Basic Ballistics

SONORAN DESERT INSTITUTE

SCHOOL OF FIREARMS TECHNOLOGY

ISBN: 978-1-945697-05-0

Rev. 8.21

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Chapter 1 - Basic Ballistics

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Introduction

Rifles and cartridges are useful only when used together. The end product of this combination is a bullet spinning through the air toward a target.

All the time, care, effort, and money expended in designing a fine rifle and cartridge culminate in the one purpose of a small, cylindrical, pointed object boring through the atmosphere at tremendous speed.

It is essential that you understand how bullets behave in flight, and what can be expected from rifles and bullets of different calibers. The science of projectiles in flight is known as *ballistics*, and basic ballistics is what this lesson is all about.

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Basic Ballistics

More and more sports enthusiasts are becoming interested in the subject of ballistics and its application to modern guns and ammunition.

The Greeks called it "ballein," meaning to *throw*. An early Roman war machine, which hurled large objects, was called the "ballista." From these ancient words, the modern term *ballistics* was derived to indicate the science of moving projectiles.

As the study of ballistics progressed, the field of ballistics was broken into two entirely different phases: interior and exterior ballistics. *Interior ballistics* pertain to performance inside the gun. *Exterior ballistics* deal with what happens to the projectile in its flight from gun muzzle to target and is of more interest to hunters and shooters because of its application to their problems. Interior ballistics are more the concern and interest of the ammunition manufacturer but are of importance when studying complete bullet performance. The gunsmith should be familiar with both.

The realm of interior ballistics extends inside the barrel from the *breech* (rear) to the *muzzle* (open end). The enlarged rear portion of the barrel accommodates the cartridge and is known as the *chamber*. Just in front of the chamber is a short conical section known as the *throat*. The area from the throat to the muzzle is called the *bore* of the gun.

The bore is either smooth or rifled. The shotgun is a smoothbore weapon. A rifled bore is so named because of the parallel grooves from 2 to as many as 12 or more, which are cut spirally up the barrel to the muzzle.

These grooves are .002 in. to .006 in. in depth and are called *rifling*. The raised portion in the bore, between two adjacent grooves is called a *land* (Figure 1). Gun calibers are commonly designated by *bore diameter*, which is the inside diameter of the barrel before the grooves are cut. *Groove diameter*, although seldom used, is measured from the bottom of one groove to the bottom of an opposite groove.

Rifling is necessary to make the bullet travel in a direct path. The longer the bullet in relation to its diameter, the faster it has to be spun. The rate of spin, or twist, in rifling varies from as many as

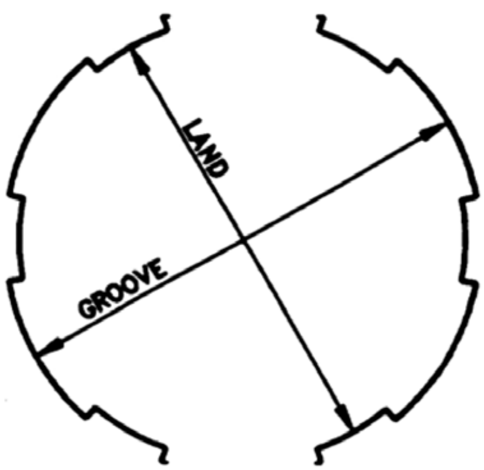


***Figure 1**: Rifling, consisting of lands and grooves, spins the fired bullet during its flight from the muzzle to the target. The spinning stabilizes the bullet in flight.*

***Figure 2:** The four parts of a cartridge are the primer, bullet, case and powder.*

one turn every 6⅓ in. to as few as one turn every 60 in., depending on the velocity, diameter, and weight of the bullet. Because there is some leeway in the amount of spin a bullet needs to maintain its gyratory stability, different bullet weights may be fired successfully and accurately from the same gun.

Cartridge cases are controlled and gauged carefully during manufacturing to assure proper functioning in all standard chambers. A case must not only chamber easily and quickly, it must withstand a tremendous expanding pressure during firing and still be extracted with ease and certainty. To compensate for this, a metallic cartridge is slightly smaller in diameter than the chamber of the gun. Under pressure of the powder gas, obturation takes place, in which the case expands against the chamber wall, making a tight seal and preventing gas from escaping to the rear. At the same time, the cartridge case head is solidly supported in the breech mechanism to prevent separation of case and head from the inside pressure. As the bullet leaves the muzzle, the pressure in the bore and chamber drops and the cartridge case shrinks enough to allow extraction from the chamber.

Each cartridge is made of four parts: case, bullet, powder, and primer, as shown in Figure 2. Case type, whether rimmed, rimless, straight, or bottleneck, is a matter of choice. Each is designed for a specific powder charge to permit the shortest, straightest, and minimum required action or breech mechanism. Proper design results in proper firing.

In a centerfire cartridge, the primer is located in a small well, or depression, in the center of the case head. It is a small cup containing the priming charge and an anvil. The priming charge is crushed against the anvil when the primer is struck and dented by the firing pin. Hot gases pass through a flash hole, which extends from the bottom of the primer well to the inside of the case, and into the powder charge for ignition.

A rimfire cartridge carries its priming mixture in the flat rim at the base of the shell. This rim also serves to locate the cartridge properly in the chamber and as a means of extracting the cartridge case after firing.

One of the major problems in interior ballistics is uniform ignition of the powder by the primer. Only by close control of ignition can uniform pressure and muzzle velocities be maintained. All modern American primers are engineered precisely to perform efficiently with modern smokeless powder.

Routine ballistic and control tests conducted by various ammunition manufacturers include pressure velocity measurements; barrel time (the time it takes a bullet to emerge from the muzzle after the firing pin falls); primer sensitivity tests; chamber gauging tests; and push and pull tests on the crimp of the bullet in the case.

Only by producing ammunition to exacting interior ballistic specifications is it possible to produce ammunition with uniform exterior ballistic performance.

The field of exterior ballistics, with its problems of air resistance, trajectory, drift, accuracy, and remaining energy, covers the study of the bullet after it leaves the muzzle of the gun.

TRAJECTORY

The pattern and curved path of a bullet in flight is known as *trajectory*. Several forces act upon a bullet to change its flight to the target.

Let's see what really happens after a bullet leaves the barrel. First, the bullet must be given a spin to keep it steady, like a spinning top, so it will stay on target. This is accomplished by the spiral lands of the rifling gripping the bullet jacket. Long bullets require a more rapid spin to stabilize than short bullets. For this reason the twist of the rifling varies according to caliber of the rifle, usually from one turn in 10 in. to one turn in 14 in. In most cases, a compromise

is adopted that is satisfactory for the different weight bullets that are available in most calibers. If both the bullet base and the muzzle of the rifle are perfectly square, the bullet will leave without tipping, which is detrimental to good accuracy. But, it is immediately affected by two main forces: gravity and air resistance.

To better understand the effect of gravity and air resistance, let's assume that we have two rifles, one shooting a 150-grain bullet, the other a 180-grain bullet. (A grain is a unit of measure equal to 1/7000 of a pound.) Both are .30 caliber and both leave the muzzle at 3,000 feet per second (fps) velocity. Let's further assume that both are on a platform with their muzzles exactly 16.08 ft. above the ground, and the axis of each barrel is exactly parallel to the ground, which in turn is perfectly level for a considerable distance away from the platform (Figure 3). Now, suppose both rifles are fired simultaneously, and that we let a bullet fall from our hand at exactly the same height, and at the exact same instant the two bullets leave the muzzle of the two rifles. What happens?

All three bullets will strike the ground at the same instant. The dropped bullet will land on the ground close to the platform: the 150-grain bullet at 2,186 ft. and the 180-grain bullet at 2,304 ft. Although both fired bullets left the guns at a rate of 3,000 fps, neither bullet will achieve that distance. Air resistance will slow down their flight, so neither can go that far in the one second that gravity will give them to fall 16.08 feet. The 150-grain bullet will be affected to the same extent as the 180-grain by the heavy hand of gravity, but it will be affected by air resistance somewhat more than the 180-grain, since the 150-grain has more surface exposed in relation to its weight.

To get back to the platform, if we could actually see the flight of these two bullets, we would notice that they were following an ever-increasing curve until they hit the ground, as shown in Figure 3. That's because the bullet is both losing velocity and dropping at an ever-increasing rate. Obviously, if we want the bullet to go farther, we have to point the barrel upward and project the bullet higher into the air, giving it more time to fall.

Even though the sight line is parallel to the ground, the bullet is rising slightly above a line projected forward from the rear and front sights (the line of sight). Figure 4 shows that in relation to the axis of the bore, the bullet begins to

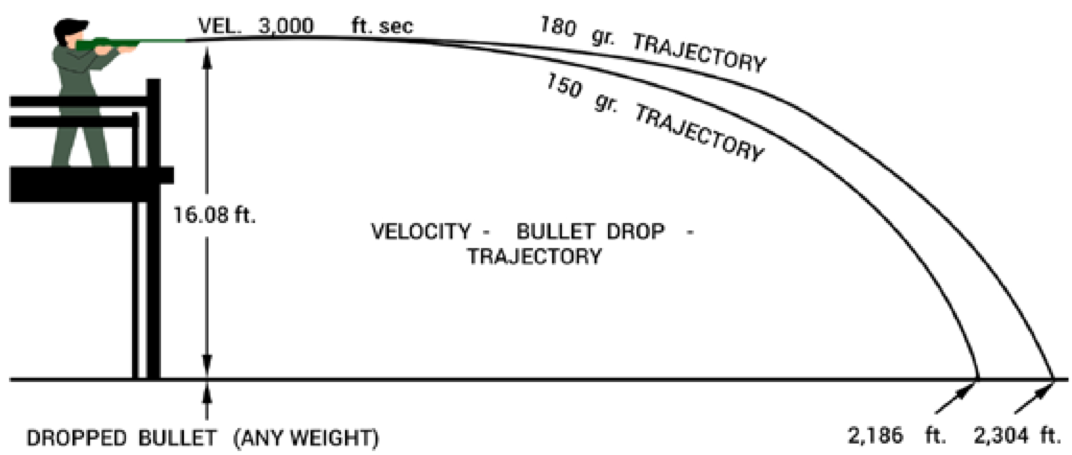


***Figure 3**: A dropped object falls 16.08 ft. in one second. All fired bullets approximate this. The higher the velocity, the flatter the trajectory. But heavier bullets sustain their velocity longer than lighter ones.*

fall the moment it leaves the muzzle, just as it did from the hypothetical 16 ft. platform. The curved path of a bullet's flight is called its trajectory. The higher the velocity, the less curve there will be over a given distance. Because the trajectory is flatter, a rifle with a higher velocity than another is called flatter shooting.

However, you do not get up on 16 ft. platforms when you shoot. You stand, or perhaps lie, prone on the ground aiming at a target about 100 or perhaps 200 yd. away. How can you be sure to hit you target? Ignoring the human element, if you have a fairly high velocity rifle, say 2,400 fps, you are certain to make a hit if your rifle is zeroed-in—sighted to hit where you aim at a measured 150 yd. If the target is only 100 yd. away, your hit will be a little high; at 150 yd., on the button; at 200 yd., a little low.

It follows that rifles with higher velocities and flatter trajectories can be zeroed-in at 200 yd. with good results at 250 to 300 yd. On the other hand, lower velocity rifles would be limited to a 100 yd. range, and either the rear sight should be raised or a higher aim taken on a target beyond 150 yd.

WIND DRIFT

Bullet flight is affected by wind drift. A crosswind, particularly one at right angles to the bullet's flight, may push the bullet off target a noticeable amount at long ranges. At short ranges, with high-velocity cartridges, the effect is small and need not be taken into account. However, wind drift will have little or no effect on a bullet that is traveling directly upwind or downwind.

In a crosswind of 10 miles an hour, a .22 caliber Long Rifle bullet, with a muzzle velocity of 1,335 fps, will be blown downwind 5 in. at 100 yd., and 17 in. at 200 yd. An identical wind will blow a 30-06, 180-grain soft-point bullet off its path 2½ in. at 300 yd. A 30 mph wind will have three times this effect.

For all practical purposes, at normal shooting ranges up to 300 yd., even in fairly heavy winds, only a small allowance is necessary for wind drift. At 400 or 500 yd., and up to 1,000 yd., ranges ordinarily shot by target shooters, the wind drift must be carefully estimated. Wind estimating requires long practice and a great amount of skill and judgment on the part of the shooter because the wind is rarely constant.

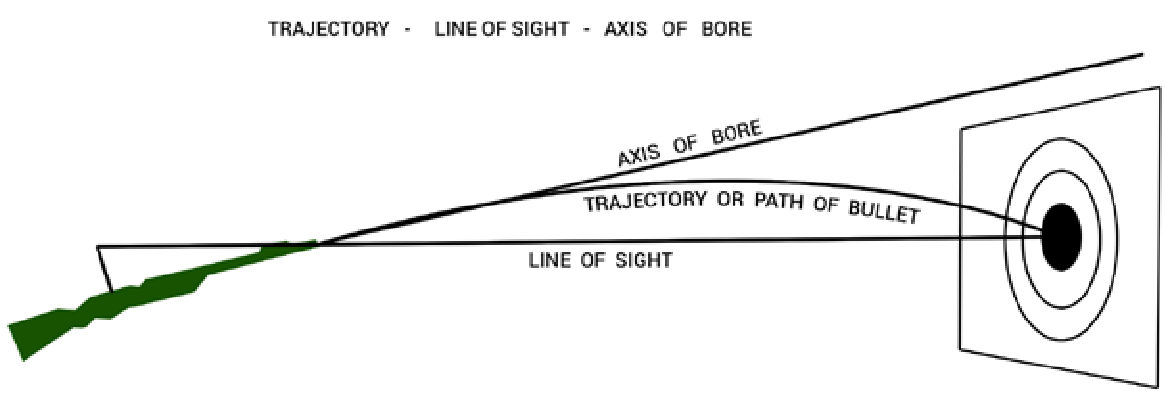


Figure 4: *For the bullet to go farther, the barrel must be pointed upwards so that the bullet is projected higher into the air, giving it more time to fall.*

BREECH PRESSURE

Questions are frequently asked concerning the amount of breech pressure, or chamber pressure, produced by a specific cartridge. This question cannot be answered with a single number of pounds per square inch since the pressure is never constant from the time the powder starts burning until the bullet leaves the barrel. For example, the maximum or peak pressure can be expressed as 50,000 lb. per square inch (PSI), but this number is entirely misleading except to the experienced ballistician.

First, this peak pressure is an instantaneous peak, so its effects are completely different than the constant or slowly changing pressures of normal experience. Only an engineer experienced in interpreting the effect of this rapidly changing pressure can apply these peak pressure measurements reliably. Second, there are such a large number of conditions that affect this measurement that a simple number of pounds per square inch is meaningless. Even an experienced ballistician cannot interpret such measurements unless the complete conditions are known.

While it becomes obvious that pressure results are almost meaningless to the layperson, they are of great importance to both gun and ammunition manufacturers.

Gun manufacturers correlate their gun designs with actual tests to make sure proper safety factors are built into their guns while ammunition manufacturers control pressures within corresponding limits.

ENERGY

Normally, energy is expressed in foot/pounds. By knowing the weight of the bullet and its velocity at the desired range, energy is easily computed. The formula is listed below.

The variables are velocity in feet per second and bullet weight in grains. The constant denominator is 450,436.

Bullet energy is of great interest to the hunter, as well as the manufacturer, because of its close relationship to killing power, which in turn is important to prevent the crippling of game. Killing power is not based on energy alone. The rate and method of application of energy to the animal is equally important. For example, a full metal case bullet may pass completely through an animal and travel on for some distance; a soft-point bullet of the same velocity will expand and deliver its entire energy within the body of the animal.

KILLING POWER

A clean kill on all types of game is the desire of a true sportsperson. The hunter desires to prevent the suffering and mutilation of his prey. No one yardstick among present published information — which includes velocity, energy, bullet types and weights, and diameter — is available that can be used to measure killing power, although the above data has some influence in determining effective killing power. All other factors being equal, it is generally accepted that within the

$$\frac{\text{Velocity x Velocity x Bullet Weight}}{450{,}436} = \text{Energy at Desired Range}$$

$$\frac{\text{fps x fps x grains}}{450{,}436} = \text{ft./lbs.}$$

Formula for finding energy at desired range.

limits of proper cartridge use, a comparison of energies is a fair comparison of killing power.

When one cartridge has a large, heavy bullet that travels at a slow speed and another has a light bullet that travels at high velocity, energy alone is not enough to make a fair comparison. For that reason, even though muzzle energies may be approximately equal, a lightweight, high-velocity bullet will tend to create a superficial wound on large game, whereas a slower and larger bullet will penetrate deeper and produce better killing power. Therefore, it is important that the proper bullet be selected.

RECOIL

Any gun that is fired has some recoil. This is true of the lightest rifles as well as the heaviest big-game guns. Bullet weight and velocity, the weight of the powder charge, and the weight of the gun affect the recoil. A lighter gun will have a heavier recoil than a heavier gun with the same cartridge.

Recoil begins the instant the bullet starts moving down the barrel. But because a rifle fires with tremendous speed, the delayed action of recoil does not affect the shooter's aim. When the bullet and powder gases have left the muzzle, the rear of the rifle has received all the recoil velocity, although it has only moved a fraction of an inch at this time. However, the gun continues to move backward against the shooter's shoulder until all recoil energy has been absorbed by the shoulder.

Ammunition manufacturers are limited as to the bullet weight and velocity that can be built into a cartridge because of a shooter's choice of gun weight and ability to withstand recoil. Increasing either bullet weight or velocity or decreasing gun weight will increase recoil, and vice versa.

VELOCITY

The forward speed of a bullet, usually specified in feet per second, is its *velocity*.

Perhaps the most interesting of all topics pertaining to exterior ballistics is velocity. The faster a bullet covers the distance from gun to target, the less it drops and the flatter its trajectory. Shooters and manufacturers search for high velocity because a flat trajectory minimizes errors in range estimation and results in surer hits at longer ranges. The need for high velocity is particularly apparent in long-range shooting.

Instantaneous muzzle velocity of any bullet cannot be measured accurately by any laboratory equipment. However, new scientific equipment, particularly the counter chronograph and photoelectric screen, make it possible to measure velocities with great accuracy over ranges as short as six feet. Loss of velocity over these short ranges is small and, thus, muzzle velocity is closely computed.

The customary method of measuring bullet velocity is to time the bullet as it passes over a specific distance. By dividing this distance by

the measured time, the average number of feet per second the bullet travels can be computed. Remember, this is the average velocity over the range on which the bullet was timed. By plotting velocities over a series of ranges, a curve can be established to estimate muzzle velocity.

A high-velocity, light- or medium-weight bullet packs a lot of energy and killing power. But to prevent its breaking on impact and creating a superficial wound, it must be very carefully and specially made. Such modern high-velocity calibers as the .257 Roberts, .270 Winchester, .30-06 Springfield, .308 Winchester, and .300 Winchester Magnum have bullets that develop the full potential of the high-velocity weapon.

EFFECT OF BARREL LENGTH ON VELOCITY

With the old black powder loads, long barrels were used to develop full velocity from the powder charge. But today, modern smokeless powders at higher pressures develop high velocity in shorter barrels. Because extremely short barrels cause some loss of velocity and excessive muzzle blast, they should be avoided.

Certain standard-length barrels, depending upon caliber, are used to measure velocities. Conditions vary widely with different cartridges and with the same cartridges in different guns. It is impossible to set an exact figure for changes in velocity per inch of barrel length above or below standard. The correction may vary from 5 to as much as 25 fps per inch. A change of 25 fps per inch of barrel, above or below standard, will be approximately correct for rifles; 6-10 ft. is acceptable for shotguns.

ACCURACY

No gun will put all its bullets through exactly the same hole on the target. Instead, the bullets striking the target form a pattern known as a *group*. The size of a group is measured by the distance between the centers of the two shots that are farthest apart. Accuracy, therefore, is the measurement of this group.

A *minute of angle* is the term used in measuring bullet dispersion and is approximately 1 in. at 100 yd. This is proportional to 2 in. at 200 yd., 3 in. at 300 yd., and so on, as shown in Figure 5. An ordinary sporting rifle is considered accurate for hunting purposes if it will shoot into three minutes of angle.

Many special target rifles and cartridges and many hunting cartridges, on the average, will shoot more accurately than the figures mentioned previously. Some of the records that have been established with modern target equipment and ammunition are truly surprising.

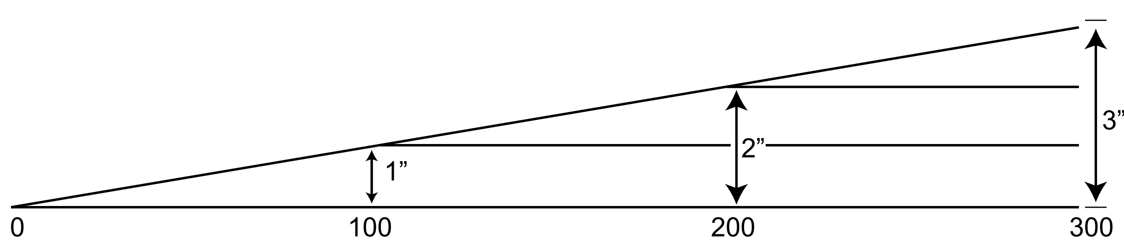


Figure 5*: This diagram illustrates the effect of sight adjustment regarding range. The base line is calibrated to 300 yd. with the angular line representing one minute of angle of sight adjustment.*

Table of Wind Allowances 22 Long Rifle High Velocity.. Deflection of Bullet In Inches and Minutes							
Distance	**Wind Velocity** *(Miles per Hour)*	**1, 5, 7, 11 o'clock Wind Direction**		**2, 4, 8, 10 o'clock Wind Direction**		**3 and 9 o'clock Wind Direction**	
		Inches	Min.	Inches	Min.	Inches	Min.
50 Yd.	5	0.33	0.66	0.57	1.14	0.66	1.32
	10	0.67	1.33	1.15	2.31	1.33	2.66
	15	1.00	1.98	1.72	3.45	1.99	3.98
	20	1.43	2.56	2.30	4.61	2.66	5.32
100 Yd.	5	1.25	1.25	2.17	2.17	2.50	2.50
	10	2.50	2.50	4.33	4.33	5.00	5.00
	15	3.75	3.75	6.50	6.50	7.50	7.70
	20	5.00	5.00	8.67	8.67	10.00	10.00
200 Yd.	5	4.28	2.14	7.42	3.71	8.56	4.28
	10	8.56	4.28	14.84	7.42	17.12	8.56
	15	12.84	6.42	22.26	11.13	25.68	12.84
	20	17.12	8.56	29.69	14.84	32.24	17.12

Gunning Calculations

The information that follows explains how to make basic gunning calculations using any calculator you have on hand. A number of examples have been provided. Online calculators are very helpful if you have access to them. One example is www.shooterscalculator.com.

Bullet Energy. To find the striking energy of a bullet when the velocity at impact and the weight of the bullet in grains are known, follow these steps:

1. Enter velocity value
2. Press the Multiplication key
3. Enter the velocity value again (to square)
4. Press Multiplication key
5. Enter bullet weight in grains
6. Press Division key
7. Enter the number 450,436
8. Press Equals key
9. Answer displayed as the striking energy in ft./lb.

Example. Let's find the striking energy of a 405-grain bullet with a velocity of 1,930 feet per second. All figures are at the muzzle.

Therefore, the energy of the 405-grain bullet at a velocity of 1,930 fps is 3,350 ft./lb.

Steps	Displayed;
1. Enter velocity value,1,930	1,930
2. Press the Multiplication key	1,930
3. Enter velocity value again, 1,930	1,930
4. Press Multiplication key	3,724,900
5. Enter weight of bullet, 405	405
6. Press Division key	1,508,584,500
7. Enter number 450,436	450,436
8. Press Equals key	3,350
9. Answer in ft./lb.	3,350

The previous example computation was done on a basic calculator. If using a scientific calculator instead, steps 1,2,3, and 4 may be combined by entering the velocity (1,930) and pressing the Square key (x2). This will give you the figure 3,724,900. The calculations will then continue with step 5.

Sectional Density. Sectional density is the weight of a bullet in relation to its diameter. It is determined by the bullet's weight (in pounds), divided by the square of its diameter (in inches). This figure is used as a gauge for determining flight characteristics. To determine sectional density, perform the following steps:

1. Enter weight of bullet in grains
2. Press Division key
3. Enter the number 7000 (to convert grains to pounds)
4. Press Division key
5. Enter bullet diameter
6. Press Division key
7. Enter bullet diameter again
8. Press Equals key
9. Answer in pounds per inch

Example. Find the sectional density of a 180-grain bullet with a diameter of .308 in.

The bullet in question has a sectional density of 0.271 lb. per inch.

Steps	Displayed;
1. Enter weight of bullet in grains	180
2. Press the Division key	180
3. Enter number 7,000	7,000
4. Press Division key	0.0257
5. Enter bullet diameter, 0.308	.308
6. Press Division key	0.0835
7. Enter bullet diameter, 0.308	.308
8. Press Equals key	0.271
9. Answer in lb. per inch	0.271

Telescopic Sight Adjustments. Many shooters mount telescopic sights on their rifles for better accuracy, as shown in Figure 6. To determine the number of clicks on the scope adjustment to move a bullet on a target a certain distance, do the following:

1. Enter the distance the bullet should move in inches
2. Press the Division key
3. Enter the number of inches that one click
   moves the bullet
4. Press the Equals key
5. Answer on panel as the number of clicks required

Example. In sighting-in a .243 Winchester rifle at 100 yd., using a Lyman 4x scope that has a ¾ in. click value at 100 yd., the first two shots are placed on the target 4½ in. to the left of the point of aim.

Steps	Displayed;
1. Enter distance the bullet should move, 4.5	4.5
2. Press the Division key	4.5
3. Enter number 0.75	0.75
4. Press Equals key	6
5. Answer as number of clicks required	6

Therefore, 6 counterclockwise clicks of the windage adjustment knob should put the bullet dead center at 100 yd.

Correcting Factory Velocity Tables. The factory-published velocities of a given load are usually based on a barrel length of 26 in., with some exceptions. To find the actual velocity in a given rifle, the following correction table may be used.

Barrel Length	Multiplication Factor
26 in.	1.000
25 in.	0.993
24 in.	0.985
23 in.	0.979
22 in.	0.969
21 in.	0.964
20 in.	0.954
19 in.	0.944
18 in.	0.939

To use this table, merely multiply the published factory velocity by the multiplication factor opposite the barrel length in question.

Example. The factory-published velocity of a 139-grain bullet in 6.5 x 54 mm cartridge is 2,580 feet per second. What is the velocity in an 18 in. carbine barrel?

Steps	Displayed;
1. Enter factory velocity	2,580
2. Press the Multiplication key	2,580
3. Enter factor from table opposite 18 in.	0.939
4. Press Equals key	2,422
5. Answer in feet per second	2,422

Therefore, the actual velocity of an 18 in. barrel is 2,422 fps

CALCULATING BULLET DROP

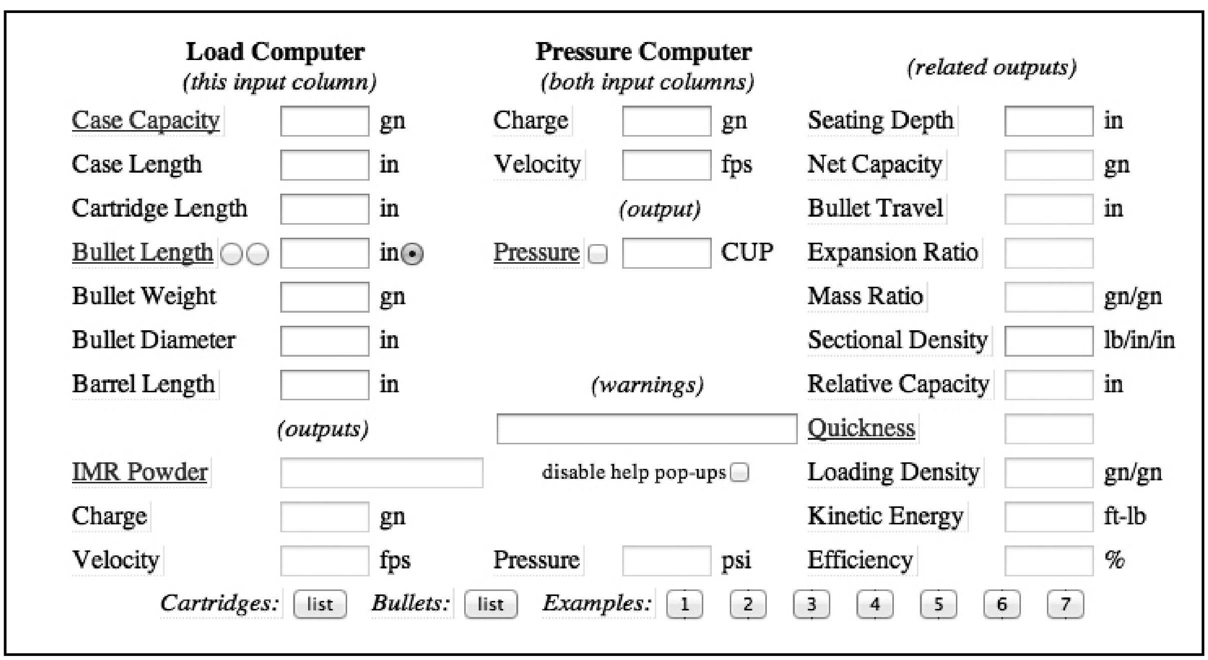
One of the more convenient devices for determining bullet drop is the Powley High Velocity Chart. This is now available online at http://kwk.us/powley.html (Figure 7). The late Homer Powley, former Chief Ballistician at Colt Industries, introduced this chart in the

Figure 6: Many shooters equip their rifles with telescopic sights. Using your calculator, you can determine quickly the number of clicks required for proper sight adjustment.

mid-1950s. To use this chart to calculate the drop of a particular bullet, the following factors must be known:

1. The actual velocity of the bullet in the rifle in which it is fired; not the published velocity.
2. The ballistics coefficient of that bullet.
3. The height of the line of sight above the bore.

The actual velocity of a bullet, fired in a given rifle, can be determined with an instrument for measuring velocity called a chronograph. These instruments are currently available from several sources at a starting price of about $80. However, for all practical purposes, the velocity for a given rifle can be estimated as discussed previously. To do so, use the published velocity for a given load (obtained from handloading manuals) and then adjust this velocity according to the barrel length given in the manual and the barrel length of the rifle in question. Use the same method of calculating the velocity as was used for the 6.5 x 54 mm cartridge in an 18 in. carbine barrel; only change the barrel length to suit the particular rifle under study.



Load Computer *(this input column)*			**Pressure Computer** *(both input columns)*			*(related outputs)*		
Case Capacity		gn	Charge		gn	Seating Depth		in
Case Length		in	Velocity		fps	Net Capacity		gn
Cartridge Length		in		*(output)*		Bullet Travel		in
Bullet Length		in	Pressure		CUP	Expansion Ratio		
Bullet Weight		gn				Mass Ratio		gn/gn
Bullet Diameter		in				Sectional Density		lb/in/in
Barrel Length		in		*(warnings)*		Relative Capacity		in
	(outputs)					Quickness		
IMR Powder			disable help pop-ups			Loading Density		gn/gn
Charge		gn				Kinetic Energy		ft-lb
Velocity		fps	Pressure		psi	Efficiency		%

Cartridges: list *Bullets:* list *Examples:* 1 2 3 4 5 6 7

Figure 7: The Powley chart is one way to determine bullet drop. It is now available online for convenient calculating.

The ballistic coefficient of a bullet determines its ability to resist air drag and maintain velocity and energy as it travels toward the target. Two methods are commonly used to determine the ballistic coefficient of a bullet. The more popular one was introduced in the 1930s by Wallace H. Coe and Edgar Beugless, ballistics engineers at Du Pont. This method compares an actual bullet to a point shape chart, and when the closest possible match is made, the chart provides a point shape factor — a number that is then divided into the bullet sectional density to give the ballistic coefficient.

The other method is direct measurement by means of firing tests. The test range must be instrumented so that both muzzle velocity and flight time over a known range are measured for each shot fired. A computer program then derives the ballistic coefficient of each test bullet from these measurements.

For the average shooter, the best and easiest way to obtain the ballistic coefficient of a given bullet is from the bullet's manufacturer. Tables, like the one shown in Figure 8, are available that give the sectional density, ballistic coefficient, etc., for nearly every bullet manufactured.

The third factor — line of sight above the bore — can vary from gun to gun, but for open sights assume ½ in., for conventional scope mounted rifles, assume 1½ in., and for scopes with see-through mounts, 2 in.

Assume that you want to find the bullet drop of a .243, 75-grain Sierra hollow point bullet fired in a .243 Winchester rifle at an actual velocity of 3,100 feet per second. Conventional scope mounts are used. The ballistic coefficient from Sierra's Reloading Manual is .265 for this bullet. With this data, we can now calculate the bullet drop using Powley's chart.

Attach the chart to the wall so that it is at a convenient height, so that it can be easily reached as you're using it. Take a piece of heavy black thread about 40 in. long and tie a thumbtack at each end of this thread. Since we are using a rifle with conventional scope mounts, one of the tacks will be placed at the 1.5 in. mark on the chart, as shown in Figure 9. We are now ready to calculate the trajectory of the .243, 75-grain bullet from muzzle to 500 yd.

The corrected (actual) velocity of our example bullet is 3,100 feet per second. Find the vertical column headed "MV" on the chart; 3,100 will be located in the lower right section of the chart. You will also find the ballistic coefficient numbers — minus the third decimal. Trace an imaginary line from the ballistic coefficient of this bullet (.265) straight across to the extreme right vertical line, which will end at curve 38. Place a thumbtack here.

Let's assume that we wish to use a 200-yd. zero, meaning the bullet will strike dead on at this distance from the muzzle. Follow curve 38 from

30 Caliber (.308″ Dia.) 165-Grain Spire Point						
Sectional Density: .248 Ballistic Coefficient: .400						
Range	**Muzzle**	**100 m.**	**200 m.**	**300 m.**	**385 m.**	**500 m.**
Velocity (fps)	3000	2735	2484	2249	2062	1827
Energy (ft./lbs.)	3298	2741	2261	1854	1558	1223
Traj.: 100 m. zero	– 1.5″	0.0″	– 4.2″	– 15.2″	– 31.2″	– 64.9″
Traj.: 200 m. zero	– 1.5″	2.1″	0.0″	– 8.8″	– 23.1″	– 54.3″
Traj.: 300 m. zero	– 1.5″	5.1″	5.9″	0.0″	– 11.7″	– 39.6″
Traj.: 385 m. zero	– 1.5″	8.1″	12.0″	9.1″	0.0″	– 24.3″
Traj.: 500 m. zero	– 1.5″	13.0″	21.8″	23.8″	18.8″	0.0″

Figure 8: Sample page from a Hornady Handbook of Cartridge Reloading showing the bullet type, sectional density, and ballistic coefficient.

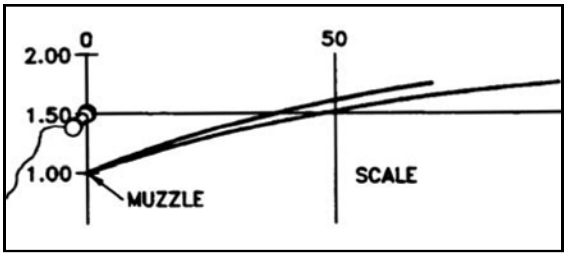


Figure 9: Place a tack, with a string attached, at the 1.5 in. mark on the Powley chart.

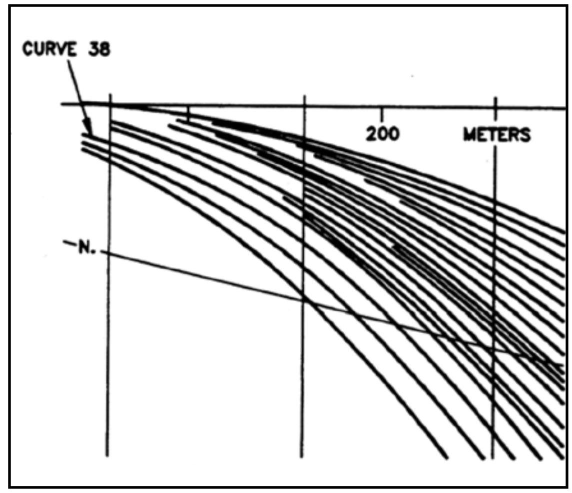


Figure 10: Make a light pencil mark where curve 38 intersects the vertical line marked 200 on the chart.

the bottom reference mark until it intersects the vertical line marked 200 on the chart. Make a light pencil mark at this intersection point (Figure 10).

Pick up the loose tack at the other end of the thread and stretch it to the right so that it crosses directly over the 200-yd. zero point that you just marked. Secure the tack to the wall, to the right of the chart. This thread represents the line of sight relative to 200-yd. zero.

Now let's calculate the bullet drop at 250 yd., 300 yd., and 400 yd. Follow curve 38 to where it intersects the vertical line marked 250. Make a light pencil mark at this point. Using a metal scale that is calibrated in tenths of an inch, measure the distance, against the 250-yd. vertical line, between the thread and the pencil mark you just made. The figure is 1.85 in., but since the chart scale is 1 in. = 2 in. (half-scale), this figure will be doubled. Therefore, 2 in. x 1.85 in. = 3.7 in. below the line of sight.

To continue, the distance (measured with the engineer's scale) from the thread to curve 38 where it intersects the 300-yd. vertical line is 4.4 in. This, doubled, would be an 8.8 in. drop at 300 yd. At 400 yd. the measured distance is 12.5 in. actual drop.

Now, let's check the Sierra Reloading Manual to see how close our figures compare to Sierra's calculations. Sierra has no figure for 250 yd., but at 300 yd. they show that this bullet will drop 7.87 in. as compared to 8.8 in. on the Powley chart—nearly an inch off. At 400 yd., Sierra shows the bullet drops 24.33 in. as compared to our 25 in. —about ⅔ in. off. However, neither case is enough of a difference to matter.

Ballistic Glossary

ANVIL: In the priming system, a fixed metallic point against which the priming mixture is crushed and thereby detonated by the action of the firing pin (Figure 11).

BALL: Early term for bullet. Still used in military nomenclature.

BALLISTICS: The study of what happens to moving projectiles in the barrel and in flight - their trajectory, force, impact and penetration.

BALLISTIC COEFFICIENT: The ratio of the sectional density of a bullet to its coefficient of form. Represents the projectile's ability to overcome the air resistance in flight.

BASE WAD: The paper filler at the rear of the powder charge of the shotgun shell.

BATTERY: The metal arm of a flintlock mechanism, against which flint strikes to create sparks in the flashpan (also called the "frizzen").

BATTERY CUP: A type of primer in which anvil and primer cup are supported in an outside cup. Shotshell primers are an example of this type.

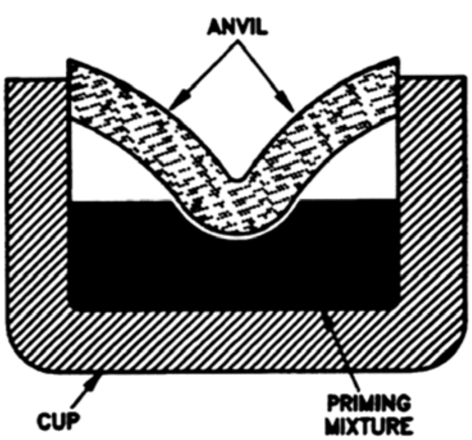


Figure 11: A cross-sectional view of a Boxer primer, showing the anvil, cup and priming mixture.

BEARING SURFACE: That portion of a bullet's surface that touches the bore in moving through the barrel.

BELT: The narrow band around the rear section of a cartridge case just forward of the extractor groove. (The belt arrests the progress of the case into the chamber and controls headspace.)

BERDAN: A type of primer with no integral anvil. The anvil is formed in the bottom of the primer pocket. This is common in Europe, but is named after Col. Hiram Berdan, the inventor, an American.

BLACK POWDER: A finely ground mixture of three basic ingredients - saltpetre (potassium nitrate), charcoal (carbon) and sulphur.

BLOWN PATTERN: A shotgun pattern with erratic shot distribution, generally caused by gas escaping past the wads and getting into the shot.

BOAT TAIL: The tapered rear end of a bullet. (Also called "taper heel", this design is used to increase ballistic efficiency at long range.)

BOLT: A steel rod-like assembly that moves back and forth in a bolt-action, sealing the cartridge in the chamber during firing.

BOLT FACE: The forward end of the bolt that supports the base of the cartridge and contains the firing pin.

BOLT THRUST: The actual force on the face of the bolt of a rifle caused by the pressure of bumming powder gases.

BORE: The inside of any gun barrel and, in rifled arms, the diameter of the barrel before the rifling is cut.

BORE DIAMETER: The measurement from one side of the bore to the other. In a rifled barrel this means measurement of the bore before the rifling grooves are cut.

Figure 12: Four types of bullets: .224, 9mm, .308, and .45. A bullet is a missile. When fired, it becomes a projectile.

BOXER: The standard American type of primer, named after the inventor, Col. Boxer, of the British Army (Figure 11).

BUCKSHOT: Large lead pellets used in shotshells.

BULLET: The missile only, which becomes a projectile when in flight (Figure 12). Not the same thing as the cartridge.

BURNING RATE: A relative term meaning the rapidity with which a given powder burns in comparison with other powders.

CALIBER: The approximate bore or groove diameter expressed in decimals of an inch, otherwise in the metric system. Frequently compounded to indicate the powder charge, the date of adoption, the case length, or the proprietor or designer; that is, .30-40, .30-06, 7 x 57mm, .375 Holland & Holland, or .257 Roberts, respectively.

CANNELURE: A groove around the circumference of a bullet or case. (For example, the lubrication grooves of lead bullets, or the grooves into which the mouth of the cartridge case is crimped, or the extractor grooves of the rimless or belted case.)

CAP: See Primer.

CARTRIDGE: A complete unit of assembled ammunition: case, powder, primer, and bullet. Usually applied only to rifle and pistol ammunition, but occasionally to shotshells (Figure 13).

Figure 13: Various types of cartridges.

CENTERFIRE: This refers to a centrally located primer in the base of metallic cartridges. Most centerfire cartridges are reloadable.

CHAMBER: That part of the bore, at the breech, formed to accept and support the cartridge.

CHARGE: The amount of propellant powder measured into the case in loading. It also refers to the amount of shot measured into the shotshell.

CHOKE: A constriction at the muzzle of a shotgun barrel, designed to control or reduce the spreading and dispersion of the shot charge.

CHRONOGRAPH: An instrument to measure the velocity of a projectile.

COCK: To set the action into position for firing. (On some firearms the action has an intermediate position called half cock. On early weapons such as the flintlock and percussion cap, the hammer was called a cock.)

COMPONENTS: Those parts that go into the making of a cartridge.

CONICAL BULLET: A cone-shaped bullet.

CORE: The part of a bullet that is covered by a jacket.

CRIMP: The portion of a cartridge case that is bent inward to hold the bullet in place, or in the case of shotshell, to hold the shot charge in place.

CUP: A detachable metal case designed to hold a number of cartridges for loading into the firearm.

DOUBLE-BASE POWDER: A rapidly burning powder made by absorbing nitroglycerine into nitrocellulose (guncotton). (Cordite is a double-base powder.)

DOUGHNUT PATTERN: A shotgun pattern with a hole in the middle generally caused by the interference of the top wad.

DRIFT: The deviation of a projectile from the line of departure due to its rotation or spin.

DROP: The distance a projectile falls, measured or calculated from the line of departure.

ENERGY: The amount of work capable of being done by a projectile at a given range, expressed in foot/pounds.

EROSION: The wearing away of the bore of an arm due to friction from the bullet or shot, or from hot powder gases.

EXTRACTOR: A hook device that pulls the case out of a chamber as the breech mechanism is opened. (The extractor generally brings the case within reach of the ejector, which then flips it out of the gun.)

FEED: The action of moving live cartridges from the magazine of a firearm into the chamber.

F.P.S.: Abbreviation for feet per second. A term used in expressing the velocity of a bullet.

FIRING PIN: The part of the breech mechanism that strikes the primer of the cartridge (Figure 14). (In most firearms, the firing pin is part of the bolt assembly.)

FLASH HOLE: The hole leading from the primer pocket into the body of the cartridge case.

***Figure 14**: Firing pin.*

FLINT: A piece of stone held in the cock of a firearm. (When it strikes the steel battery, or "frizzen," this causes a shower of sparks to fall into the flashpan and ignite the powder.)

FOOT/POUND: A unit of kinetic energy equal to the effort required to raise one pound to a height of one foot against normal gravitational force.

FREE BORE: The distance, if any, which a bullet travels upon firing before it contacts the rear portion of the rifling.

FRIZZEN: See Battery.

FULMINATE OF MERCURY: A highly sensitive explosive used as a primer compound.

GAS CHECK: A metal cup placed on the end of a lead bullet to protect the lead against the hot gases of the burning powder charge.

GRAIN: In weight measure 7,000 grains equal 1 pound; 437.5 grains equal 1 ounce.

GROOVES: Spiral cuts or impressions in the bore of a firearm which cause a bullet to spin as it moves through the barrel.

GROUP: The pattern made, at the target, of a number of shots fired with one aiming point and usually one sight setting. The size of the group is usually measured from center to center of the holes farthest from each other.

HANGFIRE: The ignition in a cartridge that is delayed beyond the normal time after the firing pin has struck the primer.

HEADSPACE: The distance between the base of the cartridge and the face of the bolt or breechlock. (This is determined by the rim of rimmed cartridges, the belt of belted cartridges and the shoulder or rimless cartridges).

HEEL: The edge of the base of the bullet.

HIGH INTENSITY: Refers to cartridges having velocities of 2,700 per second (822.96 metres per second) or more.

HIGH POWER: A term applied to the first smokeless powder cartridges with velocities of approximately 2,000 feet per second (609.6 metres per second).

HOLLOW POINT: A bullet with a nose cavity designed to increase its expansion on impact.

IGNITION: The setting on fire of the propellant powder charge by the primer.

IGNITING CHARGE: The charge used to ignite the propelling charge. (See Primer).

JACKET: The outer covering over the inner metal core of a bullet.

JAWS: The vise-like device on a flintlock hammer used to hold the flint.

KEYHOLE: The imprint of a bullet, in a target, which shows that the bullet was not traveling point-on at the time of impact.

LANDS: The spiral raised portion of a bore remaining after the grooves have been cut or formed.

LEADE: The bevelled portion of the rifling at the rear end of the barrel (and the forward portion of the chamber) where the bullet first engages the lands.

LINE OF DEPARTURE: That particular line at which a bullet leaves the muzzle of an arm. The bullet immediately falls away from this imaginary line.

LINE OF SIGHT: The straight line through the sights of a gun to the point of aim.

Figure 15: Magazines holding cartridges.

MAGAZINE: The part of a repeating firearm that holds the cartridges or shells in position ready to be loaded one at a time into the chamber (Figure 15). (The magazine may be an integral part of a firearm or a separate device attached to the action.)

MAGNUM: A cartridge or shell with greater power than normal (i.e. 300 Magnum rifle, 3 in. Magnum shotshell).

METAL CASED: A bullet with a lead core and a solid metal jacket.

METALLIC CARTRIDGE: A cartridge with a metallic case. (Early cartridge cases were made of linen, paper, etc.)

MID-RANGE TRAJECTORY: Usually refers to the highest vertical distance of a bullet above the line of sight at a point approximately halfway from the muzzle to the target, or point of aim. Sometimes abbreviated as MRT.

MINUTE-OF-ANGLE: A unit of angular deviation equal to one-fiftieth of a degree. Although usually approximated at 1 in. to the 100 yd., it is actually equal to 1.05 in. per 100 yd. Sometimes abbreviated as MOA.

MISFIRE: Complete failure of a cartridge to fire after the primer is struck by the firing pin.

MOUTH: The open end of a cartridge case into which the bullet is inserted.

MUSHROOM: The shape many bullets assume when the tip expands upon striking. Sometimes called mushroom bullets.)

MUZZLE: The front end of a barrel. The point at which a projectile leaves the barrel.

MUZZLE BLAST: The blast of the hot powder gases from the muzzle of the gun with the attendant flash and noise.

MUZZLE ENERGY: The energy of a bullet at the muzzle. See Energy.

MUZZLE VELOCITY: See Velocity.

NAKED BULLET: A bullet not covered by a metal jacket or patch.

NECK: The forward portion of a bottlenecked cartridge case. Also the portion of a rifle chamber in which the neck of the cartridge case rests.

NOSE: The point of a projectile.

OGIVE: The radius of the curve of the bullet nose, usually expressed in calibers.

PATTERN: The way a shotgun places its shot load. Generally measured as the percentage of a full shot charge that is placed in a 30 in. circle at 40 yd.

PENETRATION: The distance travelled by a projectile from the point where it strikes the target to the point where it stops.

PERCUSSION CAP: A small metal explosive-filled cup that is placed over the nipple of a percussion firearm. (As the cap is struck by the hammer, it explodes and sends a flame through the flashhole in the nipple to the main powder charge.)

POWDER: The propellant material used in most firearms. Divided into two basic types: smokeless powder and black powder. It is

produced in a wide variety of types, forms, and brand names intended for specific applications.

PRESSURE: The pressure exerted by a burning charge of powder in the chamber of a gun. Normally expressed as the peak pressure in pounds per square inch (PSI).

PRIMER: Also called cap, deriving from percussion cap, which is the priming form used with some muzzleloading arms. In a centerfire cartridge, the small metal cup containing a detonating mixture which is used to ignite the propellant powder. The primer is seated in the primer pocket in the base of the cartridge case. The standard American type of primer, the Boxer, also contains an anvil. In a rimfire cartridge, the priming mixture is contained within the rim of the case.

PRIMER CUP: The housing in a shotgun cartridge base that holds a primer.

PRIMER POCKET: The depression in the base of a centrefire cartridge that contains the primer.

PROJECTILE: A bullet or shot in flight after discharge from a firearm.

PROPELLANT: The chemical substance that imparts movement to the projectile in a firearm.

PUMPKIN BALL: A large round ball of lead used in shotguns. (These projectiles are the same size as the shotgun bore.)

PYRITES: A mineral used to produce sparks in primitive firearms. (It was replaced by flint.)

RAMROD: A wood or metal rod used to force the wad and bullet down the barrel of a muzzleloading firearm.

RANGE: The distance travelled by a projectile from the firearm to the target. "Pointblank range" is the distance a projectile will travel before it drops the extent that sight adjustment is required. "Effective range" is the greatest distance a projectile will travel with accuracy. "Extreme range" is the maximum distance a projectile will travel. Also, a facility designed for the safe shooting of firearms.

RIFLING: Parallel spiral grooves cut or impressed into the bore of rifles and pistols in order to make the bullets spin, insuring a steady, point-on flight to the target (Figure 16).

RIFLED SLUG: A large, single projectile used in shotguns.

RIM: The edge on the base of a cartridge case that stops the progress of the case into the chamber. (It's also the part of the case the extractor grips to remove it from the chamber.)

RIMFIRE: Cartridges that contain the priming mixture within the rim. This type is not reloadable under practical conditions.

***Figure 16**: View of rifling inside a barrel.*

Figure 17: Round nose bullet.

ROUND NOSE: A blunt, spherical, nose-shaped bullet design feature (Figure 17).

SECTIONAL DENSITY: A bullet's weight (in pounds), divided by the square of its diameter (in inches).

SHANK: The cylindrical section of a bullet.

SHOT: The lead alloy spheres, sometimes copper or nickel-plated, which are used for the projectiles in smoothbore guns (shotguns).

SHOULDER: The sloped or rounded part of a bottlenecked cartridge case.

SLUG: A cup-shaped, hollow-base projectile, usually bearing external precut rifling, intended for adapting shotguns to the hunting of larger game, such as deer. Also used as another term for bullet.

SOFT-POINT: A bullet design feature with a portion of the lead alloy core exposed at the point or nose of a jacketed bullet.

SPENT BULLET: A projectile which has lost nearly all its energy and lacks the force needed to penetrate the target.

SPITZER: A bullet with a sharp point for better stability during flight.

STRIKER: The front part of a firing pin that strikes the cartridge.

THROAT: That area of the bore immediately ahead of the chamber that tapers to the point where the rifling starts. Also called leade.

TRAJECTORY: The path of the projectile in flight.

TWIST: The angle of the rifling in relation to the axis of the bore. Usually measured by the length of barrel required to make one complete turn.

VELOCITY: The speed at which a projectile travels. Usually measured in feet per second (fps) at a given range.

WAD: A disc used to separate powder from shot, to seal propellant gases behind the shot; or to hold shot together in the barrel.

WILDCAT: A cartridge case formed by altering an existing case to make a shape of case that is not available from the large ammunition companies. A nonstandard cartridge case.

NOTES

NOTES

Chapter 2 - Development of the Modern Cartridge

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Introduction

Guns and ammunition are integral parts of shooting and can hardly be considered separately.

Until about 125 years ago, a cartridge was a lead ball or bullet plus a charge of powder wrapped in a paper case, called a *cartouche*, the French word for cartridge. These early cartridges, like the one shown in Figure 1, were usually carried in a cartridge pouch. To load them into the rifle or musket, the shooter would tear off the end containing the powder charge, dump the powder down the muzzle, and, using the torn paper as a wad, ram the remainder with the bullet down the barrel with the ramrod. If the shooter was using a flintlock, he would pour a small amount of fine powder into the "pan." If

he had a percussion gun, he would slip a cap on the nipple. In either case, he would be ready to fire when the hammer was thumbed back to full cock.

Cartridges went through several stages of development before becoming today's self-contained cartridge, in which the projectile or small shot, powder, and the primer are all cased together. Modern rifle and pistol cartridges have metallic cases and use either a rimfire or centerfire ignition system, depending on the type of priming.

Cartridges come in a variety of sizes and calibers. Usually, modern cartridges have descriptive names that were assigned by the original manufacturer. The caliber of the cartridge is indicated either by hundredths or thousandths of an inch in the United States and Canada, by thousandths of an inch in the United Kingdom, and by millimeters elsewhere. The caliber figure sometimes refers to the bore diameter between the lands of the rifling or between the grooves, and it sometimes refers to the diameter of the bullet.

The object of this lesson is to trace the development of the modern cartridge, including its primer, powder, and bullet. In doing so, you will learn about the initial development of metallic cartridges. You should then be able to identify most cartridges and the firearms for which they were developed. You will also be introduced to collector cartridges and will learn how to appraise them. Finally, you will receive an introduction to the lessons on advanced ballistics and handloading ammunition that follow.

Cartridge Development

One of the first self-contained cartridges to gain success was the .44 Henry rimfire cartridge, developed by B. Tyler Henry of New Haven, Connecticut. It was originally chambered for the Henry lever-action rifle, which was the forerunner of the first Winchester — the Winchester Model 1866 lever-action rifle. The bullet was roughly 0.44 in. in diameter.

Henry was a shop superintendent for the New Haven Arms Company in 1859 when he was given the task of redesigning their Volcanic rifle action. The new action had to be suitable for use with rimfire metallic cartridges. The first public record of Henry's direct participation in the design of the repeating action appears in U.S. Patent No. 30446, granted to Henry on October 16, 1860, for an "improvement in magazine firearms."

New features of the Henry rifle consisted principally of the addition of a two-prong firing pin, which struck on opposite sides of the flanged head of the rimfire cartridge; an extractor; and changes in the bolt and feeding mechanism. The system satisfactorily handled the loading and firing of the rimfire cartridge and the extraction and ejection of the empty, fired shell. The slotted tubular magazine under the barrel held fifteen 44-pointed rimfire cartridges. Henry later developed the .44 Henry flat cartridge, which was the answer to metallic cartridge arms. This cartridge was important to the development of firearms, especially repeating firearms. All successful guns on the market at the time, such as the Sharps, were single-shot weapons. Henry and Oliver Winchester wanted to develop a repeater, because they recognized the advantages of this type of weapon.

As a result, B. Tyler Henry completely revolutionized the firearms industry, and Henry rifles immediately became popular. The name Henry has been perpetuated in still another manner. If you buy a box of Winchester rimfire cartridges of any caliber, you will notice a trademark, a simple H, stamped on the head of each case. This is Winchester's tribute to B. Tyler Henry, and since that first .44 Henry rimfire cartridge was produced, every Winchester rimfire has been identified with an H (Figure 2).

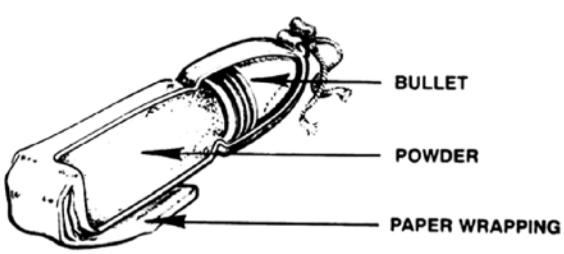

***Figure 1**: Muzzleloading cartridge for military rifle/musket.*

***Figure 2**: Every rimfire cartridge developed by Winchester has an H stamped on the cartridge head as a tribute to B. Tyler Henry.*

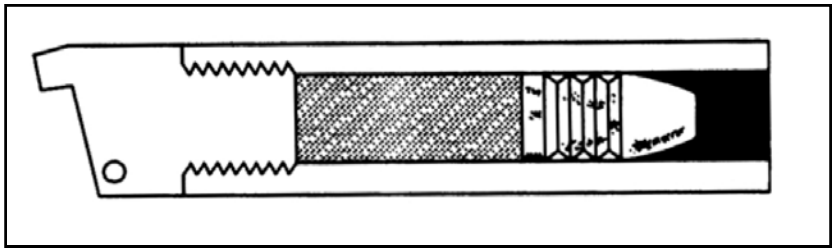

***Figure 3**: The famous Minié ball was a great improvement over earlier projectiles used in firearms.*

Until the introduction of the self-contained cartridge to America, firearms development had been extremely slow. The major problem was in the method of charging a gun, which could mean the difference between life and death in the heat of battle. Even early muzzleloading cartridges had their problems. Although they offered a great advantage over the loose powder-and-ball system, they were still extremely slow.

A brief resumé of military developments shows the general trend of the firearms field in this respect. Until 1844, all military arms used a round ball. Smooth bores used just the ball, but when used in rifled barrels, the ball was wrapped in some sort of a patch cloth — linen, leather, or some similar material. The problem with the rifled barrel was that it was hard to find a bullet that would expand to fill the grooves, reducing the loss of powder gases that would leak past the bullet. To get a bullet to fit so tightly in the bottoms of the grooves required an oversized barrel, which created the problem of the shooter having to shove the bullet through the muzzle and down the whole length— sometimes nearly 4 ft. — of a fouled barrel.

One early development in firearms was the Minié rifle. Designed in 1847 by French army captain Claude-Etienne Minié, the rifle fired a conical ball with an iron cup in the base (Figure 3). The conical ball had a somewhat hollow base with a wedge-shaped cup, and it could be made slightly undersized. The blast of the powder gases upon ignition forced the iron cup into the base of the bullet, expanding it to fill the rifling promptly. This increased the speed of loading as well as accuracy.

Another early development dates back to 1826, when Captain Henri-Gustave Delvigne of France introduced to the French government an improved form of rifle capable of being loaded as quickly as a musket. The improvement consisted of giving the powder chamber a reduced diameter to form a shoulder on which the ball rested when seated to its full depth. When struck two or three times with a ramrod, the ball expanded to completely fill the grooves upon being shot.

The Delvigne system of chamber was adopted by France in 1838. In 1840, Delvigne took out

an additional patent on an explosive bullet with an elongated, cylindrical design, which later proved unsuitable for general military use.

In 1844, Colonel Thouvenin of the French Army proposed an improvement to the round ball. This improvement consisted of a short pillar screwed into the breech plug on which the ball could rest, and which upon being struck by the ramrod would expand like the Delvigne chamber system. Captains Minié and Tamasier of the school of musketry of Vincennes suggested the use of a cylindro-conoidal bullet with a solid base. This was adopted by the French government in combination with the pillar breech in 1846.

Captain Tamasier also reduced the depth of the grooves from the breech to the muzzle. This greatly increased accuracy. This system was used almost all the way through American arms developments. Therefore, the development of American shoulder arms can be traced to the French rather than to the English.

Captain Tamasier also developed the idea of grooving the bullet with two or three sharp-edged channels on the cylindrical rear end, reducing the resistance and permitting easier expansion to fill the grooves. It is not known whether his ideas included the addition of lubricant to these grooves.

Minié's most important contribution to the problem concerned the bullet. His first pattern had a solid cone base united by a short, grooved neck to a rounded head. After Tamasier proved the advantage of more grooves with shoulders like saw teeth, to act more or less as dirt scrapers, Minié combined two of these with a hollow base in which an iron cap was inserted and driven halfway up the bullet on firing. This had a sphere-conodial head.

In the English edition of the Minié rifle, the exterior grooves characteristic of the Delvigne-Tamasier-Minié bullet were omitted. In this rifle, the bore of the barrel was about 0.577 in. with three grooves having one turn in 6 ft. 6 in. The conical bullet had no grooves, but a hollow base in which a conical slug was placed. Initially made of boxwood, it later was made of baked clay to allow for expansion. This made an excellent weapon for a muzzleloader and was supplied to all troops in the British service.

Between 1849 and 1855, the U.S. government experimented with firearms, using the Model 1841 rifle, then the 1842 musket with the .69 caliber round ball, and the 1854 conversion of the 1822 and 1842 muskets to a .58 caliber rifle, using the conical bullet. Finally, in 1854 they began preparation for replacing (in 1856) the smoothbore with a rifled barrel in all branches of service.

After experimenting with Capt. Minié's bullet containing an iron wedge, Assistant-Master Armorer Burton of the Harper's Ferry Armory found that a plug was unnecessary because the gases from the explosion sufficiently expanded the hollow base. The plugless bullet was adopted and used thereafter in all new muzzleloading rifles.

Although the extremely slow loose powder-and-ball loading system was still used, some progress was being made (Figure 4). For example, in the paper cartridge unit, the conical ball was wrapped in a patch with a properly measured amount of powder and inserted in a paper tube behind the ball.

Although the idea of wrapping the ball and powder together was not new, many authorities still believe that the United States developed it. However, records show that King Gustavus

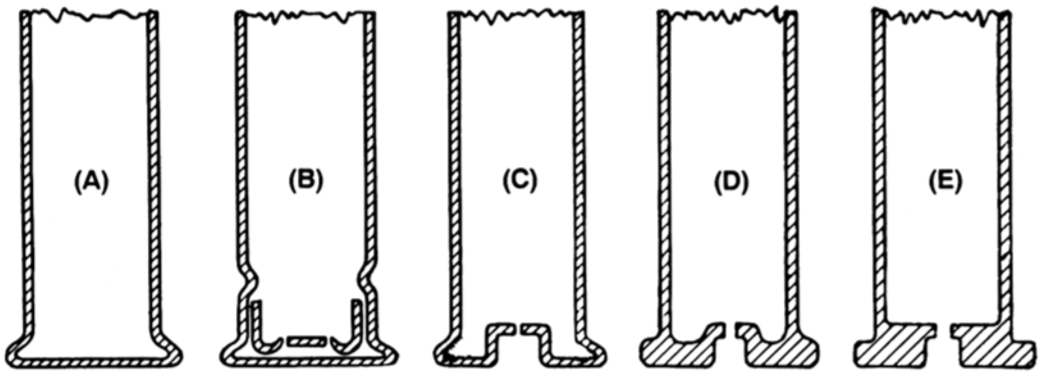

Figure 4: Evolution of the cartridge case. (A) Rimfire. (B) Benét cup-type inside primer. (C) Original folded head with centerfire. (D) Original solid-head centerfire, sometimes called semi-balloon primer pocket. (E) Modern, solid-head solid web.

Adolphus of Sweden ordered his soldiers to carry their powder and ball together in the form of a cartridge in the early 1600s. This cartridge consisted of a cylinder of paper that was twisted on both ends with a round lead ball in one end and a measured charge of black powder poured in on top of it.

The next major development was the unit cartridge with a combustible envelope, which was manufactured by Colt and others, both for early handguns and for rifles. The paper was heavily nitrated, making it extremely combustible. The entire unit, paper and all, was dropped in the muzzle of the gun and seated with a ramrod. If the paper broke open in the seating operation, it was perfectly all right. If not, it would ignite anyway and no traces were left in the barrel.

Next came the development of the famous Sharps linen. This was similar to the combustible envelope or paper cartridge, but the cartridge was wrapped in linen and thoroughly sealed. These cartridges withstood far more abuse than the paper variety and proved extremely popular when used in Sharps rifles.

The Sharps was a breechloader, and the early linen cartridges were shoved, bullet first, into the chamber with the breech cam open. The closing of the breech caused the block to rise up and a sharp edge sheared the end off the linen powder chamber. The muzzle was usually lowered during this operation to prevent powder spillage. Once closed, the percussion cap—the Maynard tape primer—formed ignition through the customary flash hole in the breech.

In 1851, Maynard patented the brass cartridge. This consisted of a tubular brass case with a wide, flat base soldered to the body. In the center of the head of the case was a small needle hole, and the case was used in conjunction with the Maynard tape primer as a breechloader (Figure 5).

In England, the .577 Snider incorporated this coiled cartridge case, which consisted of a combination brass and steel head with the body built up of thin layers of brass foil and paper. This was rolled around in a mandrel to form a paper-metal "sandwich" with the edge solidly

***Figure 5**: The Maynard cartridge had a tubular base with a wide, flat base soldered onto the body.*

glued and was used from 1867 to 1871 as the official firearm of the British military forces. According to *The British Small Arms Manual*, it was designed by Colonel Boxer of the Royal Laboratory at Woolwich Arsenal.

In 1871 the Snider was dropped in favor of the .577/450 Martini-Henry, one of the first attempts in England to bottleneck a cartridge case. The case had a .577 caliber Snider body necked down to hold a .45-caliber bullet, as shown in Figure 6.

One of the earliest American brass cases was the Burnside. This carbine, which was used in tremendous quantities during the Civil War until the time of the Custer Massacre, used a straight shell tapered from front to rear, with a large conical bullet that had a bulge or heavy ring on its rear end. Around this ring the neck of the case was formed and crimped. The cartridge was loaded from the front of the tilting chamber, similar to the early Hall rifles described previously. It is quite possible that Burnside got his idea from Hall. Since the mouth of this shell was formed around the base of the bullet and securely crimped into position, its design was unique.

The Burnside carbine used external ignition in either the form of a percussion cap or the Maynard tape primer. The base of the cartridge had a flash hole perforated to line up with the nipple in the breech so that it would ignite the powder charge inside.

The rimfire cartridge was the first truly successful metallic cartridge because it was fairly moisture-proof and its three major components — powder, primer, and bullet — were entirely self-contained. All of the early rimfires had copper cases. Burnside, Maynard, Sharps, and other old gun inventors had to depend upon some form of percussion-cap ignition with the cartridge case containing only powder and ball and ignited through the head of the cases.

A French gunsmith, Louis Flobert, pioneered the now famous BB (bullet breech) caps. Smith & Wesson was the first in the United States to develop a successful rimfire cartridge — the now-common .22 short, first produced for revolvers in 1858.

The rimfire used today is essentially the same as at the time of its origin. A copper disc is punched from sheet metal and then drawn by means of

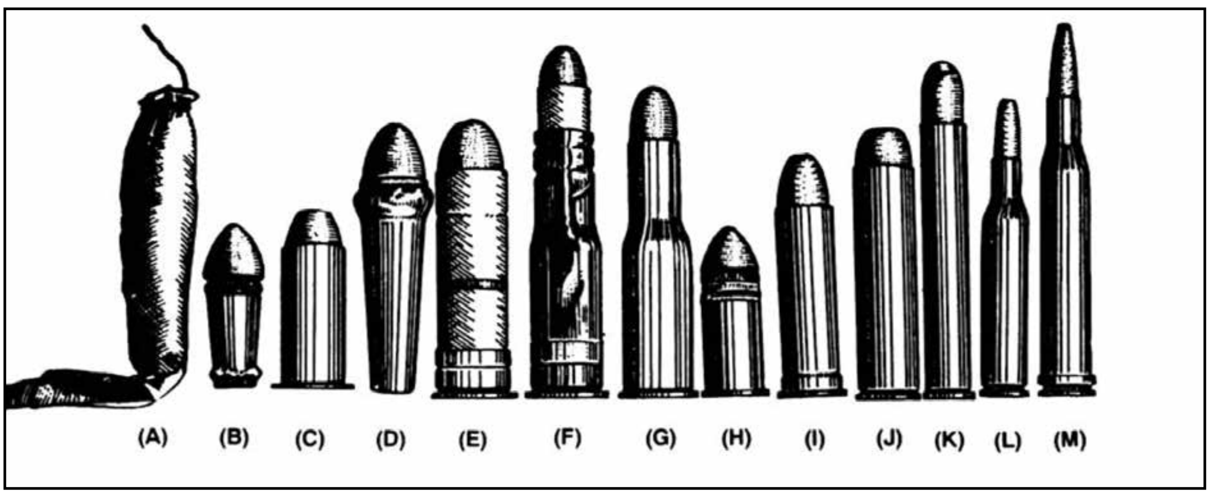

Figure 6: *Evolution of the modern cartridge case. (A) The old paper cartridge for muzzleloading percussion muskets. (B) The paper cartridge for Colt revolvers. (C) The Maynard percussion rifle cartridge with wide thin rim soldered to the base of the shell. (D) The Burnside percussion carbine. (E) The .577 Snider coiled cartridge case. (F) The .557/.450 Martini-Henry coiled case. (G) A solid drawn .577/.450 Martini-Henry. (H) The .58 musket rimfire. (I) The .50/.70 Springfield Armory. (J) The .50/.115 Bullard centerfire with semi-rimmed head. (K) The .405 Winchester. (L) The .257 Roberts rimless. (M) The .300 H&H Magnum belted head.*

punches and dies into a closed-in tube. The rim is then bumped on. This hollow rim is filled with a mixture of priming compound, originally pure fulminate of mercury. This explodes when the rim is pinched between the face of the barrel and the firing pin or hammer nose.

B. Tyler Henry adapted the famous .22 rimfire to a larger size, producing the .44 Henry cartridge, the first successful "high-power" magazine arm. The development of ammunition was also progressing rapidly at this time. Rimfires had their weak points — they were inclined to blowout at the rim upon receiving the blow of the hammer, greatly limiting their power.

Many interesting developments in metallic cartridges have been made. Morse's cartridge, patented in 1858, was made in Frankford Arsenal in 1860 in small quantities. This distinctive device had a brass cartridge case, the rim of which was folded on the outside to make a tube. The head itself was of gum elastic inserted in the base in the form of a stopper. Into this was inserted a primer similar to a percussion cap. A large anvil, curved to fit the inside of the case, was securely attached, and a flash hole perforated the center. Very little data are available on this, and it is somewhat doubtful if it worked.

Records show that Frankford Arsenal made the Burnside cartridge in 1860 using a 400-grain, .45 caliber ball. Although thousands of these cartridges were made later, at Frankford, various commercial enterprises also manufactured it.

Frankford Arsenal also manufactured the Maynard in .45 caliber. Although this was also commercially manufactured in several other calibers, and Maynard later introduced a series of cartridges of his own, the original Maynard was first made at Frankford Arsenal in 1860, using a .45 caliber bullet, 40 grains of black powder, and a 343-grain slug.

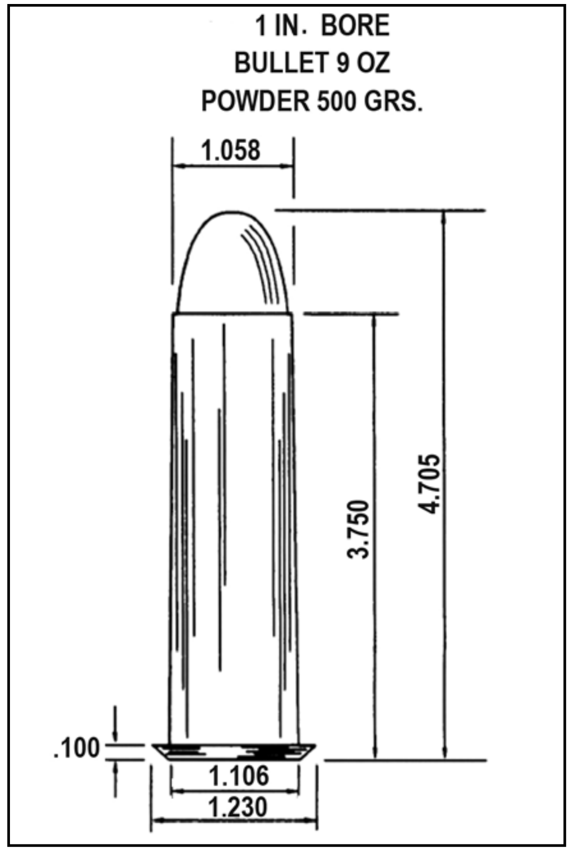

Figure 7: *The 1 in. caliber Gatling cartridge was one of the largest until the development of cannon shells.*

The Spencer cartridge, patented in 1860, was another of the first successful rimfire cartridges. It was first made experimentally by Smith & Wesson in 1857. It consisted of a .50 caliber bullet weighing 450 grains, backed by 40 grains of black powder. About 50,000 were manufactured at Frankford Arsenal in 1864 and 1865, and they were primed by one of the early centrifugal machines that spun the wet composition into the rim. They used the mixture specified by Sharps: six parts (by weight) of mealed powder, three parts fulminate of mercury, and three parts powdered glass.

Prior to 1866, the Frankford Arsenal had only manufactured the Morse, Burnside, Maynard, and rimfire cartridges of various sizes. The largest of these, shown in Figure 7, was the experimental 1 in. caliber Gatling gun cartridge, a large rimfire made to test an experimental Gatling gun. Early tests showed that the centerfire had the greatest possibilities, so efforts were concentrated in this direction.

The first experiment with centerfires at Frankford began in 1864. Two attempts were made with a rimfire cartridge head. The first, with an anvil inserted in the center of the case head, was supported in the center of the powder charge and against the base of the bullet. However, it proved to be unsatisfactory.

The second attempt used a flat bar anvil with a bulge on the head. This anvil pressed solidly against the base of the cartridge, acting as a gas check or reinforcement and at the same time as an anvil. Two flash holes permitted ignition to the powder charge.

The third attempt used external priming. The head of the rimfire cartridge case was bumped into a pocket similar to the present-day pocket and was perforated with two flash holes. The priming mixture was then thrust into this pocket with a thin copper disc pressed overall to seal the pocket completely. It worked, but it leaked gas badly, and the copper disc invariably blew out.

A further development used the standard rimfire case with star-shaped punching with a pocket in the bottom. This star-shaped punching was crimped into the rim to form a suspended pocket. A small anvil with a regular percussion cap over it was previously inserted in this pocket. Striking the apparent rimfire cartridge in the center of the head jammed the copper cap against the anvil. Tests show that 50 of these were fired and there were no failures. It was the best development to that date.

In 1865, Colonel Laidley patented a design that used a large, thin H of sheet iron with an anvil formed on the crossbar. A standard rimfire case was used that was tapered at its forward end so that the anvil could not be blown out and get lodged in the barrel.

This was modified with Laidley's second development, which had straight sides to the anvil rather than the H construction. A deep crimp in the side of the case secured the side walls, thus eliminating the necessity of continuing the iron support to the base of the bullet.

The Ordnance of 1870 gives a description of another priming development. In 1866, a wet composition was deposited centrally on the bottom of the case, adhering sufficiently to the metal when dry, and surrounded by compressed gunpowder. The Ordnance describes it as follows:

> *The powder itself formed the anvil and the priming was ignited with the regular firing pin blow. Twenty cartridges were fired, with one failure. The composition was very sensitive and great care was necessary in loading to avoid explosion. It could become detached in transportation and in service.*

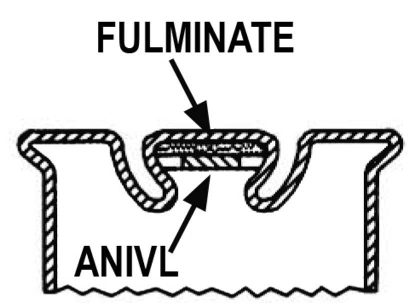

Figure 8: *One of the most practical developments of a centerfire primer was the Martin bar anvil.*

One of the most practical developments of a centerfire primer was the standard Martin bar anvil, shown in Figure 8. This was first manufactured in the .50/70 Government musket caliber in which a 450-grain, 3-groove bullet was propelled by 70 grains of black powder.

The bar anvil was made of iron and consisted of a bar with a groove in its rim. In the top center was a cavity to hold the priming composition, which was placed in the bottom of the cartridge case against the head. The case was then crimped into the rim to hold it in place. This was first manufactured at Frankford Arsenal in 1866, and was discontinued in 1868, due to the large number of defects associated with it. The chief problem was in the manufacture. Many of the anvils would tip upon being seated by machinery and explode.

Some of these bar-anvil cartridges were used in the 1 in. caliber Gatling gun cartridge. The semi-conical nose bullet weighed 8 oz. and had a diameter of 1.025 in. Official reports show that it was first made as a rimfire in 1865 for an experiment. A tinned-iron bar anvil was used in the manufacture of about 100,000 ball-and-canister loads in 1867.

According to the Ordnance report of 1873, the bar-anvil cartridge was first made at the national armory in Springfield, Massachusetts, in 1866. E. H. Martin, an armory employee, invented it for experimental purposes. The Ordnance states:

> *It consisted of a copper case and a rigid tinned-iron anvil recessed at the center to hold the percussion composition and grooved in the ends for crimping and securing it in place. Several million were manufactured at Frankford from October 1866 to March 1868 when it was replaced by Colonel Benét's cup-anvil cartridge.*

Several problems were associated with the bar anvil. It was occasionally thrown into the barrel of the gun when firing; it could be turned upside down; and crimping the case close to the head drew in the flange, producing tension and causing occasional bursting. In 1867, a cup reinforcement made from thin metal was applied to the inside of the metallic cartridge case to prevent the gases from reaching the fold. This remedied the problem that caused bursting, but caused occasional misfires from two thicknesses of metal at the point of impact on the firing pin.

This was alleviated by a cup or reinforcement that was inserted within the flange cartridge case in such a manner as to rover and protect the flange.

BLANK CARTRIDGES

It is believed that the first of the military blank cartridges like the one shown in Figure 9 were manufactured at Frankford Arsenal in 1868. The 1873 report shows a drawing of a .50/70 musket blank cartridge using the Benét cup-type primer, and the report states:

> *The above service blank cartridge was adopted September 1868. The end was tapered to assist its entrance into the gun chamber and to have the smallest wax seal possible. The wax is composed of 15 lbs. beeswax, 1 lb. resin, and 1 gal. North Carolina pine tar melted together; and is applied cold by pressing in by hand. Cartridges have been made for the following arms: the Navy rifle, the Spencer rifle, Gatling guns, and Colt, Remington, and Smith & Wesson pistols. This metal is from .022 in. to .025 in. of copper.*

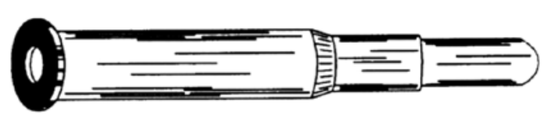

***Figure 9**: It is believed that blank cartridges were first manufactured around the late 1860s.*

Another experimental center-primed cartridge was designed by Benét and manufactured at Frankford Arsenal from January to April 1866. In this particular cartridge the case was formed like a rimfire but the primer pocket was shaped as a continuous drawing with the head of the case. In other words, it was "bumped-in" in the conventional fashion.

This particular idea was one of the principal features of the Berdan cartridge. Colonel Berdan came to the arsenal and obtained the necessary information to apply to his own cartridge, which previously had a separate cup inserted at the head. In the Benét cup the anvil was inserted separately and a percussion cap then pressed in on top. This used a single, central flash hole.

Still another development, the Crispin, a combination paper-and-metal wrapped cartridge case, was manufactured in 1867 at Frankford Arsenal for experiment based on plans submitted by Colonel Cyrus Crispin of the Ordnance Department.

The plans specified that a strip of thin sheet of brass about .002 in. thick be rolled by hand on a roller along with a sheet of paper, forming a case of three thicknesses of paper and two of metal. The paper was to cover the inside and the outside of the case, with the metal between. The case was to be held to a brass head or capped by the friction of a paper wad in the head.

Although a number of these Crispin cases were fired and proved to be easy to extract, this mode of attaching was not considered reliable, because the case frequently came loose from the head. The head, which was similar to Colonel Benét's center-primed design, had the primer pocket folded into the original head, along the lines of a modern shotgun shell.

Another development of the metallic cartridge was for the Thuer alteration of the Colt revolver. This was a rimless metallic cartridge with a primer located in the center, but the case itself was tapered slightly toward the rear and was loaded from the front of the cylinder. A number of these used a standard center fire primer, as is evidenced by specimens in collections. The early development used the Benét cup-type primer and was made as an experiment at Frankford Arsenal for use in the first alteration of the Colt Army revolver in November 1868. It was inserted in the chamber in the front end, held in place by the friction of the bullet, and ignited at the center by a firing pin. The friction of the bullet, however, was not always sufficient to ensure ignition, resulting in many misfires. A cartridge made with a thin cap and outside priming was much more efficient.

Another development was that of the Martin cartridge, patented and manufactured experimentally in 1869.

The Martin cartridge had a complicated system in which the copper case was folded so that it appeared to have an inserted centerfire primer. Actually, the primer was a part of the original case drawing. The case was first drawn along the lines of a rimfire, a very large primer pocket almost the full diameter of the head was bumped in, and the primer pocket was then pushed upward by a small center punch to form a flat surface with the head of the cartridge. This resulted in a fold or copper case, which projected into the powder chamber. Into this pocket an anvil was inserted and hollowed out which contained the priming composition. The composition was seated into this special pocket with the folds crimped around the anvil to hold it in position.

The patent claims granted to Edward H. Martin in 1869 follow:

> *U.S. Patent No. 88,191. Claim: First, an interior conical-shaped pocket or receptacle containing the fulminate and anvil where the wall of said pocket is formed in two thicknesses of metal contiguous to each other substantially as described.*
>
> *Second, turning over the upper part of the conical portion of the reinforcing cup upon and into the pocket or receptacle for the fulminate an anvil forming a gas check substantially as described.*

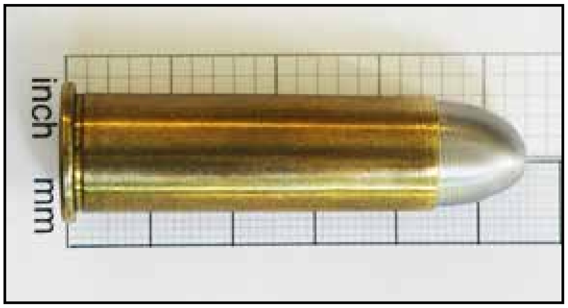

***Figure 10**: The .50/.70 government cartridge was one of the first successful centerfire cartridges.*

A number of these cartridges were made at Frankford Arsenal in 1871 for the Navy carbine, Remington pistol, and Colt revolver, calibers .44 and .50. The unique feature of the cartridge was the formation of an inside pocket from one continuous piece of metal and is performed at two operations.

During 1870, Martin received a patent for a modified design in which another fold was added under the head to prevent burst rims. This was patented under U.S. No. 111,856.

Frankford Arsenal records show that a large number of the Martin cartridges caliber .50/70, shown in Figure 10, were made from May to December 1871. The formation of the fold required two operations, and the inventor used a single-indented bar anvil that was primed by hand plates and was used until the machine charger was finished.

A double-indented bar anvil replaced the single bar in September 1871, and in October 1871, Colonel Treadwell suggested a double-indented disc anvil with one vent.

The hand-priming often caused the composition to burn when closing the pocket on the anvil on the double-indented, machine-primed bars. The disc had the advantage of a larger surface to resist the pressure of crimping or fastening the anvil, reducing the burning to a minimum. The bars exploded upon loading at a rate of 1-5 in each 1,000, while the use of the disc reduced this rate to 1 in 10,000.

A unique feature of the cartridge was the formation of the inside pocket to hold the anvil in a fold of one continuous piece of metal. The double fold at the head gave elasticity at the weakest point. Early experiments showed that occasionally the crimp on the bullet would pull the case body off the head and drag it into the barrel before the pressure of the cartridge could expand the case. Manufacture of this type of cartridge was abandoned in December 1871.

Another development was the Corliss needle cartridge with the Springfield breechloading rifle. The needle was attached at the base to a disc crimped into the flange of the case. The point was made to conform with that of the service firing pin, and the fulminate was held in a copper capsule seated in the base of the bullet, open to the rear and covered with tinfoil. A blow from the standard firing pin against the priming composition ignited the powder charge from the front.

Most of these early experimental cartridges were handmade and were held to very close precision requirements. Official tests show that the first 25 cartridges tested failed entirely to explode in the gun. On examination, the fulminate was found to have been forced into the bullet instead of being crushed by the needle point.

An additional 30 cartridges were made with the front of the needle flat and squared. Out of 18 tested, 5 exploded. Average velocity with the same weight of powder and bullet charge of the service number with a cup primer was 1,320 feet per second; with the needle it was 1,336 feet per second. The variation in the standard service (rear ignition of powder charge) was .3 percent

and of the needle 1.1 percent. The front ignition gave slightly higher velocity but no uniformity.

In an accuracy test of 500 yd., average deviation with the service cartridge was .856 in., with the needle it was 2.169 in. The fouling from 14 shots was removed and weighed. In the service cartridge it amounted to 6 grains; with the needle cartridge it was 5 grains. Of the 13 needle cartridges used in this test, one cartridge exploded on the first blow, 3 on the second blow, 6 on the third blow, 2 on the fourth blow, and 1 on the fifth blow. Five needle cartridges failed entirely after five blows. This particular idea was never placed into practical application.

Further experiments were conducted with a new type of reloadable centerfire cartridge, with a primer designed by Milbank and patented in May 1870. A number of these manufactured by the Winchester Repeating Arms Company of New Haven, Connecticut, and labeled "solid head, central-fire reloading cartridges" were tested at Frankford Arsenal in April 1873. The head was claimed to be a solid one, which was presumed to mean one fold, similar to that used in the standard Dutch carbine cartridge (Beaumont).

According to Frankford Arsenal, this did not fulfill the conditions of solid head as they rated it. The metal of the case was quite thick, measuring .05 in. The flanges or rims had a greater variation in thickness than any other cartridge previously tested at Frankford and ran from .062 to .079 in. Frankford reported that they even varied in thickness on the same rim at different points, showing bad work at a very important point.

The primer was made similar to a rimfire case, and a pocket was bumped into the standard case head for insertion of this separate primer.

The official Frankford Arsenal report shows that the composition "is of a dark color resembling that in the Eley cap and is covered by a paper wad, the open end being slightly closed to facilitate its insertion into the pocket of the case." In submitting this, Winchester claimed superiority in the following points: first, certainty of fire; second, no escaping gas at the primer; third, resistance to moisture, and fourth, facility in reloading.

RELOADABLE CARTRIDGE CASES

Frankford Arsenal developed an interesting experimental case for reloading. One of these experiments, conducted in 1872, used a conventional folded-head cartridge case built like a rimfire but with a large opening in the center. Into this was inserted a cup also open in the center, to serve as a gas check. Through the opening, a special pocket was riveted into position. A separate anvil of brass used a percussion-cap type of primer curved to hold the anvil in position. Twenty cartridges were made from brass rather than copper, and a Remington gun was used for experimental purposes in .50/70 musket caliber. The results showed no signs of swelled heads, and extraction was extremely easy.

Photo of Frankford Arsenal Government Loading Bullets.

Within a year many of these Frankford Arsenal experimental features appeared in a patent granted to Milbank No. 131,017, dated September 1872.

Another Frankford Arsenal experimental case for reloading had the primer pocket formed as a part of the original draw and a special gas-check cup perforated in the center and forwarded around the primer pocket and the rim of the case to give added strength. In these tests, twin flash holes were used and two types of anvils were tested – one a cube and the other a sphere.

The idea was to secure a proper position in the pocket when machine loaded without careful inspection. Experimental spheres were made by casting ordinary type metal (a hard lead and antimony mixture). Twenty were fired with one failure. The alloy proved too soft and difficult to mold.

The cube was made of brass, .12 in. on its edge, by punching in a double-action press, and the flat surface was toward the priming composition, but was not as sensitive as the pointed anvil. The cap surface was spherical along the lines of the Winchester primer today. The priming mixture was thickest in the center.

Moist priming was used to charge these little cups, and a mixture of glass and tinfoil was varnished on after they dried. The tinfoil was secured by a varnish cement and could be revarnished on the top of the tinfoil to seal against moisture absorption. The diameter of the pocket cap was .22 in. and depth of the pocket .19 in. The thickness of the metal was .036 in.

It was intended to use a punch to remove this anvil and the fired cap, whereupon the brass anvil could be reinserted and reused.

A third idea experimented with at Frankford Arsenal is a type today known as the *Berdan anvil*, in which the anvil forms a definite part of the primer pocket and thus is not removable. This proved to be a very reliable cartridge.

A large number of these cartridges were made for the Russian government for use as a reloader. The cartridge has a very different value from the center-anvil type and its effectiveness as a reloader is questionable.

The original Frankford Arsenal off-center anvil used a single large flash hole whereas the Berdan used two small flash holes located on opposite sides of the pocket bottom.

Many ideas for both inside and outside primers were tested at Frankford Arsenal, with varying degrees of success.

SOLID-HEAD CARTRIDGES

It is believed that the Hotchkiss was the first true solid- head cartridge. This had a solid head with no folds at the rim. The sharp corners were not the product of stamping or drawing but more or less of lathe turning. The primer pocket was not visible from the exterior. The pocket consisted of a cup formed in the bottom of the head on the inside.

An inverted anvil containing the priming composition was dropped into this cup. The pocket was then crimped to the anvil to prevent the anvil from blowing out. A blow of the firing pin on the outside of the head indented the head against the priming composition. The anvil thus exploded the mixture and permitted it to escape through a central flash hole in the powder charge. However, the cartridge was not reloadable.

Cartridge development continued in various ways. Numerous commercial developments (too many to recount here) proved to be successful mainly on paper, since in actual tests they usually failed. The majority of those ideas that proved to be reasonably practical were probably submitted for government testing, since every inventor, whether commercial or individual, was interested in securing development of his or her ideas by the government for possible adoption. This would result in excellent revenue for the manufacturer or inventor.

***Figure 11**: Winchester claims their 6 mm Lee Navy was the first rimless cartridge developed in the United States.*

RIMLESS CARTRIDGES

The history of the first rimless cartridge is uncertain. Winchester takes credit for producing the first successful rimless cartridge in this country, the 6 mm Lee Navy, shown in Figure 11. It is also quite possible that the .50/115 Bullard was the first rimless cartridge.

Regardless of which came first, the rimless cartridge presented additional problems for cartridge case manufacture.

Essentially, a rimless cartridge case is the same as the rimmed type, but with the rim lathe turned off and an extractor groove cut into the brass head. The solid-head construction did not have sufficient metal to permit this.

This resulted in the development of solid-web construction, which is used in most of today's cartridge cases. With the exception of cases for a few small pistols and revolvers, all automatic pistol cartridge cases are solid web, as are those of the majority of modern revolvers.

The primer used these days is not really new. For nearly fifty years it has been constructed essentially the same way. Only minor changes in developments have been made. Some primers use two-legged anvils, some use three-legged ones, and some use four-legged ones. Some early Savage primers made over 75 years ago show brass cups with four-legged brass anvils.

The major change caused by smokeless powder was the elimination of mercuric fulminate for the priming mixture. Mercury attacks brass, causing the metal to become brittle and dangerous for reloading purposes. Frankford Arsenal developed the first successful priming mixture, H-48, which was designed for the .30/40 Krag cartridge and first produced around 1898. This was the standard government primer for many years. The priming was nonmercuric and was copied by many commercial ammunition makers almost from its introduction.

The mercuric primer worked fairly well with black powder, but this powder left a heavy residue inside the brass case, which minimized the problem of the mercury attacking the brass. With smokeless powder this residue was not present and destruction was rapid, so the mercuric primer went out of existence, particularly on shells designed to be reloaded.

There has been little development of the cartridge case in recent years. Early cases were either straight or straight taper. Modern high-power rifle cartridges are more or less of bottleneck type of construction, allowing a much larger space for powder in a given caliber.

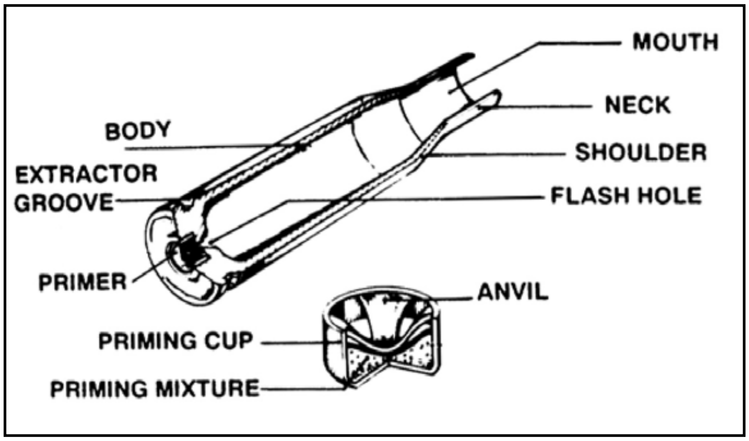

Figure 12*: Components of a modern centerfire cartridge case and primer.*

Figure 12 shows a cutaway of a modern cartridge and primer.

Brass has remained the standard for centerfire cases although experimental materials have been tried. Due to a shortage of brass during World War I, Germany used steel cases. Although these were expensive to manufacture, they worked fairly well. Many soldiers brought back samples of these. Most of the steel cases were heavily copper plated to prevent rust.

Frankford Arsenal also experimented with steel cases to determine if they could be manufactured under wartime requirements in case of a brass shortage. Experimental samples were found to be entirely practical, but the manufacturing expense along with the failure of the cases to expand properly in the gun eliminated them as a possibility.

Cartridge Identification

Because cartridges vary so widely in origin, characteristics, and description, no universal or standard naming system has ever been adopted.

In the early days, centerfire cartridges were designated by a system of two or three numbers. For example, the .45-70-500 cartridge told the shooter that the bullet was .45 caliber, the powder charge was 70 grains, and the bullet weighed 500 grains. The .32-20 was approximately .32 calibers and contained 20 grains of black powder. The .44-40 was approximately .44 calibers and contained 40 grains of black powder.

The .30-40 Krag is a little different. It was a .30 caliber cartridge backed with 40 grains of smokeless powder, and its inventor's name (Krag) was added.

The .30-06 Springfield is an example of cartridges named according to date or origin. The .30 caliber Springfield rifle, first adopted by the U.S. government in 1903, was modified in 1906 to take the present cartridge. This explains the "06" in the name.

Sometimes, the name of the maker or manufacturer is added to a cartridge designation, distinguishing it from another cartridge of the same caliber but different makeup. For example, the .25-20 Winchester was named to distinguish it from the .25-20 Single Shot — an entirely different cartridge.

In the .270 Winchester, the manufacturer's name (Winchester) is added after the caliber designation. The .257 Roberts is named after its inventor, while the .303 British is named for the country in which it was developed.

RIFLE CARTRIDGES	
AMERICAN	**EUROPEAN**
22 Hornet	5.6 x 35R
22 Savage	5.6 x 52R
25 Remington	6.5 x 52
25-35 Winchester	6.5 x 52R
7 mm Mauser	7 x 57
30-30 Winchester	7.62 x 51R
7.62 Russian	7.62 x 54R
30-06 Springfield	7.62 x 63
303 British	.303" Mark VI or VII
8 mm Mannlicher-Schaonauer (M1908)	8 x 56
8 mm Mauser	8 x 57
PISTOL CARTRIDGES	
AMERICAN	**EUROPEAN**
25 Automatic	6.35 Browning
30 Luger	7.65 mm (Parabellum)
30 mm Mauser	7.63 mm Militaire
32 Automatic	7.65 mm Browning
38 Automatic	9 mm Browning
380 Automatic	9 mm Browning Short (Corto, Kurz)
9 mm Luger	9 mm Luger (Parabellum)

***Figure 13**: A comparison of some American and European rifle and pistol cartridges.*

Because foreign countries use a different system of weights and measures, some foreign cartridges are designated in millimeters instead of inches, as with the 7 x 57 mm Mauser. In this cartridge the bullet diameter is approximately 7 mm, the length of the cartridge case is 57 mm, and the inventor's name was Mauser (he was also the manufacturer). Almost all European rifle cartridges are designated in this manner. Foreign rimmed cartridges carry the letter R following the cartridge designation.

Typical of European rimless cartridges is the 8 x 57 mm cartridge, which has an 8 mm bullet and a case 57 mm long. The same cartridge in the United States is referred to as the 8 mm Mauser, or the 8 x 57 or 7.9 Mauser, to avoid confusion with the 8 x 56 Mannlicher-Schöenauer. Both cartridges are rimless and closely resemble each other.

Several American calibers have become popular in Europe, and guns to match them have been made in those countries—usually with a different name, as shown in the chart in Figure 13. It is difficult to determine the interchangeability of American and European cartridges because many cartridge names between the two countries are totally different. A wrong choice could cause a serious accident.

It is a good idea to check any foreign gun thoroughly especially if caliber and condition are not readily known before you attempt to fire it. Follow these procedures when checking the gun:

- Slug the barrel to determine the exact bore diameter. This is done by pushing a slightly oversized pure lead bullet down the bore with a rod. Then, with calipers or a micrometer, carefully measure the diameter of the lands and grooves cut into the lead bullet.

- Make a chamber cast using Cerrosafe compound and take all measurements with a micrometer. By comparing these dimensions, you should be able to determine the cartridge type from reference books. *Cartridges of the World: A Complete and Illustrated Reference for Over 1500 Cartridges* by Frank C. Barnes is one of the better references. A three-volume set of books titled *Cartridges for Collectors* by Fred A. Datig is another excellent reference source.

- Check the headspace with the proper headspace gauge.

Many foreign rifles, especially those made during wartime, were often made by slave labor, of shoddy materials, and many were assembled from scattered parts — some of which may not have been fitted properly. Improper headspace and even more serious problems may be present.

CARTRIDGE COLLECTING

Collecting cartridges is an interesting hobby, and such a collection will also prove invaluable to the gunsmith in identifying foreign and obsolete cartridges. You can identify many unmarked obsolete firearms by using cartridges in your collection as references. Now would be a good time to start such a collection.

Most cartridge collections probably evolved by the accumulation of odds and ends that accompanied collector firearms. Consider the following example: A collector purchases a Winchester Model 1886 rifle chambered for a .40-82 Winchester. Along with this rifle comes a partial box of original, factory-loaded ammunition. Later, the collector sells or trades the rifle, but keeps the cartridges. The collector purchases another firearm, for example a Remington Rolling Block single-shot rifle chambered for the Remington .44-100-500 cartridge. Again, a few cartridges are included in the deal. Eventually, after several purchases of this nature, the gun collector or dealer has what could be considered a cartridge collection, which grew more or less by accident.

Let's stop and see if you can identify the two cartridges mentioned in this example. How

would you describe the .40-82 Winchester? If you said a .40 caliber cartridge containing 82 grains of powder and introduced by Winchester Repeating Arms Company, you are right! Now how about the Remington .44-100-500? This is a .44 caliber cartridge containing 100 grains of powder behind a 500-grain bullet. It was introduced by Remington Arms Company.

If the collector has enough interest in old or unusual ammunition, he or she will probably specialize in one area of cartridge collecting; for example, cartridges grouped by brand, country of origin, caliber, or perhaps in military ammunition. The study of only one small group of cartridges will reveal information previously unknown to the collector. He or she will learn facts that will help identify headstamps, case metals, bullet shapes, and designs, just to name a few.

At this point, the cartridge collector will start investigating the best methods to catalog and store the collection, build up trading stock, maintain the collection, and similar details. He or she will also be looking for methods of evaluating the worth of the collection.

Not too many years ago, obsolete cartridges of all types could be found in attics, basements, at flea markets, gun shows, and other places..all for a relatively reasonable price. However, many of the early obsolete cartridges have risen in value to the point where many beginning collectors are eliminated at the outset. The investment required to purchase and maintain such a collection can be very discouraging to the would-be collector. Still, these rare specimens can be found from time to time, and rather than collect them, the finder may wish to sell them to an established cartridge collector.

Price guides are available that give the worth of collector cartridges, but since prices are changing on a continual basis, these references should be used only as guides. Look in some of the shooting publications, like *Shotgun News*, *Gun Digest*, and *American Gunsmith*. Locate antique cartridge dealers online or in the classified ads in these publications and request their current price lists, which will give you a relatively accurate value of collector cartridge. Another reference for antique cartridge prices, as well as antique firearms, is *Antique Guns — The Collector's Guide,* published by John E. Traister, available at online book retailers.

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Modern Bullets

The samples shown in Figure 14 illustrate the wide variety of bullets made for rifle and handgun ammunition. There are bullets for target shooting, big game shooting, small-game hunting, self-defense, police work, and even for special gallery use. Each is discussed in the paragraphs that follow in order to familiarize you with the various types and their uses.

LEAD BULLETS

Lead bullets are made of an alloy — in this case, a mixture of lead and antimony — that produces a harder bullet than one of pure lead.

Plain lead bullets must be greased or lubricated either "inside" or "outside" to prevent leading or fouling of the gun bore. Bullets lubricated inside are provided with grease retaining knurls that are filled before the bullet is loaded into the case. This lubrication is covered by the case after loading so that the lubrication does not pick up grit or other foreign matter.

Outside-lubricated bullets are greased after loading, and the bullet is generally completely covered with lubricant.

All factory bullet lubricants are combinations of waxes and grease that give maximum accuracy, prevent fouling or leading, and prevent the tendency to melt or run during hot weather.

JACKETED BULLETS

A jacketed bullet has a lead core covered by an outside jacket of gliding metal. These jackets are especially alloyed for toughness and non-fouling characteristics. This prevents the bullet from deforming after firing and sends it out of the bore entirely free of unwanted fouling. The jackets and cores are assembled into several styles of bullets — full metal case, soft-point, hollow point, etc.

Figure 14: Several types of bullets currently available to shooters and reloaders.

FULL METAL JACKET

The full metal jacket or case has a metal jacket completely enclosing the tip of the bullet, preventing it from expanding when it reaches a target.

The pointed or spitzer type of bullet is used in target shooting. The sharp profile gives less wind resistance, flatter trajectories, higher remaining velocities, minimum wind drift, and top accuracy. Round-nosed bullets with lower velocities are used for sure functioning in semi-automatic firearms.

SOFT-POINT BULLETS

When a jacketed bullet is closed at the base and has a part of its core exposed at the point, it is called a soft-point bullet. In factory-loaded bullets and those for use in hand-loading, the amount of lead exposed at the tip, jacket thickness, and hardness of the core are controlled carefully for proper performance within the velocity range of each cartridge.

When a soft-point bullet strikes game, the point expands and upsets or mushrooms. The energy of the bullet is expended quickly within the animal, creating shock and a large wound. In medium calibers and at ordinary ranges, the soft-point is very effective on thin-skinned game. In heavy calibers, these bullets are designed for positive performance on larger game.

HOLLOW POINT BULLETS

As Figure 14 shows, the hollow point bullet has a cavity at the tip, which gives it expansion characteristics different from the soft-point. Hollow point expansion is delayed, giving deep penetration. Its explosive opening action causes great tissue destruction. For positive stopping power of heavy, thick-skinned game, the hollow point has no equal for preference — particularly when the trophy is more valued than the meat and destruction of tissue is of little importance.

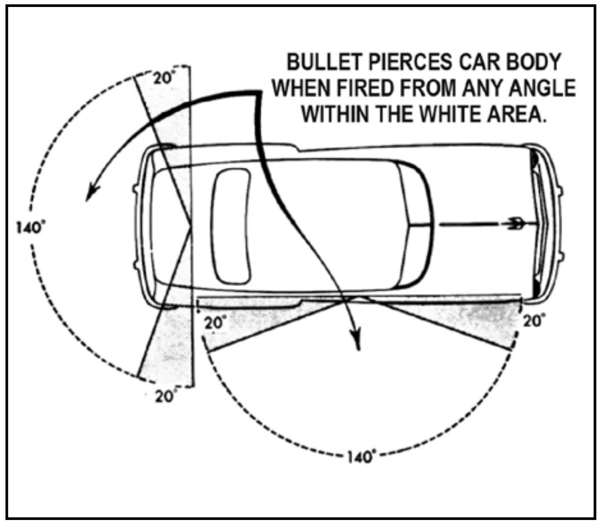

***Figure 15**: Despite the sloping designs of today's automobiles, metal-piercing bullets will penetrate from any side, even at a 20° angle.*

WAD-CUTTING BULLETS

These bullets were designed especially for target shooting, but in recent years, law enforcement agencies have found that these blunt, sharp-shoulder bullets tend to ricochet less than round-nosed bullets, and consequently are safer for use where a stray bullet may injure an innocent bystander. These bullets cut a clean hole through target paper and are therefore easier to spot and score.

METAL-PIERCING BULLETS

Developed especially for law enforcement officers, the metal-piercing bullets are used to stop criminals escaping in fast automobiles. The bullet's nose is conical in shape and is made of tough gliding metal. It punches its way through the steel body of the car and is carried on by the weight of the lead core or body of the bullet. This bullet does an effective job of stopping a criminal. Refer to Figure 15.

SAFETY GEAR

- A work area with good ventilation; outside is best (not in your kitchen or a garage)
- Safety glasses – eyeglasses, range safety glasses, or a full-face clear grinding shield
- A pair of heavy work gloves, such as heavy welding gloves
- A sturdy surface to hold your burner and lead pot
- Closed-toe shoes
- A good A,B,C fire extinguisher
- Long sleeve pants and shirt
- Respirator mask

Casting Basics

As projectile material, lead predates firearms by centuries. Roman slingers used cast lead bullets alongside stones and ceramic spheres. All through the Medieval and early Renaissance periods, lead bullets were used in arbalests or bullet crossbows. The infamous Chevalier de Bayard, "the knight without fear and beyond reproach," known for mutilating enemy arquebusiers and crossbowmen, fell to such a lead bullet in 1524. It remains an open debate whether the bullet that penetrated his armor came from a firearm or a crossbow, since both were referred to as "arquebus" at the time. Compared to other options, lead was dense enough for good downrange performance and easy enough to cast under field conditions. Melting at just over 600°F and soft enough to be cut with a knife,

WARNING

Casting can be very dangerous if the proper precautions have not been taken. There are several facets of the casting process that can be dangerous to both yourself and others around you. Lead itself is toxic and is known to cause cancer. When casting, you will be exposed not only to lead in its solid form, but also in its molten form and as hazardous fumes. Additionally, you will be exposed to other fumes from impurities in the lead burning off during melting. There is also a great risk of severe burns from molten lead. Common sense and an established safety regimen will reduce any risk and prevent accidents or injury.

Casting should be performed in a well-ventilated area, preferably outside. When casting outdoors, the area needs to be covered to prevent unwanted moisture from contacting the molten lead and causing it to erupt violently and spit molten lead everywhere. Moisture from sweat can also cause the molten lead to erupt. All tools used for casting should only be used for casting and nothing else. You will also need to keep an ABC (the three classes of fires) fire extinguisher on hand.

When casting, you should only wear clothes made from cotton or other natural materials. Molten lead will melt synthetic materials to your skin and cause greater injury. You will still suffer some injury with natural fibers but not nearly as bad as with synthetic clothing. You may want to wear an apron over your clothing to prevent further lead exposure when mixing your clothing in the hamper.

Safety glasses should be worn at all times. A full face shield is best. Because it is important to limit the amount of skin exposed, you will want to wear a long sleeve shirt, long pants, and closed-toe shoes, preferably boots. You will also want to wear heavy leather gloves, such as welder’s gloves. Lastly, it is recommended that you wear a respirator; dust masks will not work.

It is possible for lead to be absorbed into the skin. It can also be ingested or inhaled. When casting, do not touch your mouth, nose, eyes, or ears. After you are done casting, wash your hands and face with cold water (to avoid opening your pores). Wash casting clothes separately from the rest of the laundry. When finished casting, clean up the work area and make sure to turn off any machines. Keep small children away from the casting area and any exposed lead.

Casting is an enjoyable hobby and can be very safe when caution is taken. Complacency in routine or distractions can lead to mistakes and possible injury. Make sure to always pay close attention to the task at hand when casting to avoid any accidents. Maintaining a safety routine will ensure you always stay safe and free of injury.

Figure 1: Pepperbox revolver roundball.

lead could be made into bullets over a campfire. Considering the absence of bore standardization, the ability of individual soldiers to make their own bullets was a distinct plus.

With the invention of rifling in the early 16th century, lead's softness was also appreciated for better obturation than stone. The downside of lead was its high price relative to stone, which is why cannonballs went to pig iron as soon as it became possible. Similarly, WWII small arms ammunition contained less dense iron — not because lead was inferior, but because it was in short supply. Pure lead bullets gave way to harder cast alloys, and paper patching was added, but unjacketed lead remained the material of choice until the 1890s (Figure 1). For many uses, unjacketed bullets remain superior and more economical projectiles compared to either jacketed or machined copper projectiles. Most recently, polymer coatings mitigated some of the traditional problems with lead, like dust generation and inability to hold rifling past certain velocity. Today, lead casting is alive and well on both industrial and hobby levels.

Figure 2: Lead casting is alive and well on both hobby levels and industrial levels.

Originally, bullets were cast one by one by individual hunters or soldiers to fit the bore sizes of their guns. Typically, the bullets were cast undersized using pure lead, and then brought closer to exact fit with paper or leather patching. With muzzleloading rifles, bullets were engraved by the rifling during the loading process, which made it slow and physically strenuous. With the improvement of gunpowder quality in the late 18th century, and with the transition to smaller bore — from 18 mm down to 11 mm —by the third quarter of the 19th century, harder lead alloys came into use. The addition of small amounts of tin and antimony hardened lead considerably for better engraving on rifling, concurrently reducing the melting temperature. Pure lead melts at around 621˚F, while 89-11 alloy with antimony liquefies at only 477˚F, with either lesser or greater percentage raising the melting point toward the original value and even higher.

Figure 3: A thermometer is key to getting accurate melting temperature.

Once the melting point has been established, lead should be kept at it and no higher. Boiling the liquid would increase the amount of airborne fumes, and would also mix lighter impurities back into the mix. With lead just at melting point, various contaminants float at the top and do not enter the bullet forms filled from the

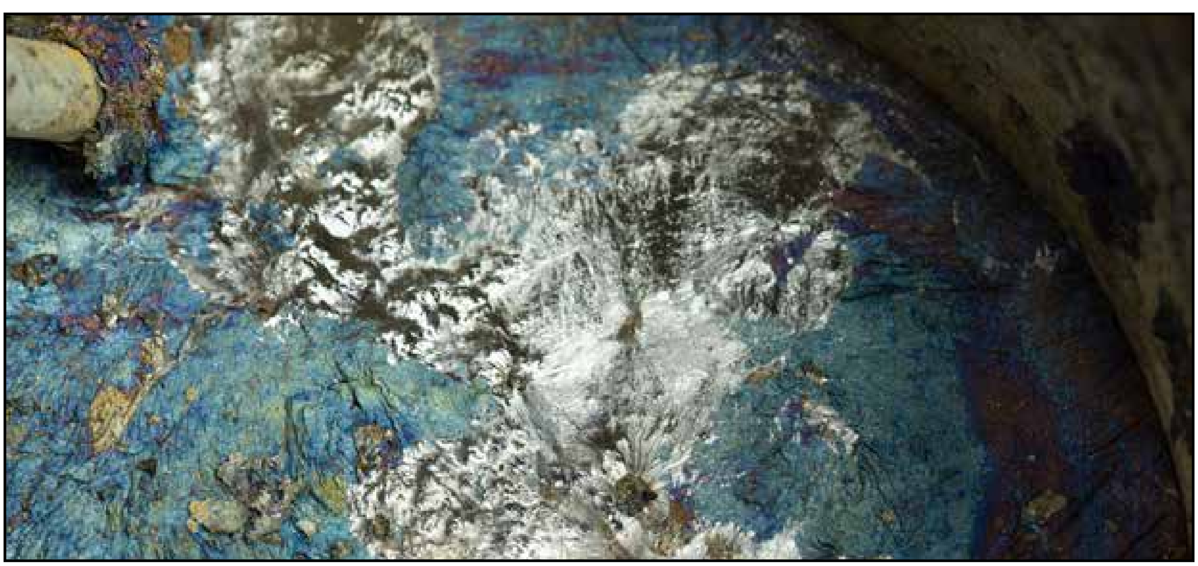
Figure 4: Lead impurities.

Figure 5: Casting.

bottom of the container. Overheating the metal is also wasteful of energy and slows down the cooling of the poured portions inside molds.

Manually operated molds usually have one, two, or four cavities (Figure 5). The automated rotary caster has eight two-cavity molds filled and emptied sequentially. The difference in productivity is about ten-fold, from 400 bullets per hour to around 4,000, not counting the time required for additional steps like polymer coating and final sizing. Unlike the classic single-cavity molds (Figure 7) used by the pre-modern shooters, modern molds have such a close fit between halves that the seam is of negligible

Figure 6: Cast bullets.

Figure 7: Gang mold sprue.

Figure 8: Overfilled mold.

dimensions, so cutting off the sprue or molding flash is not necessary. With manually operated molds, overfilling should be controlled to avoid waste of metal and effort. Under-filled molds are also a problem, and a more serious one at that, resulting in malformed projectiles.

Soft lead works well for smoothbores and low velocity rifled firearms. As pressure rises and velocity increases, harder bullets become necessary to keep from slipping off the rifling and smearing material in the grooves. While it is possible to quench lead to harden it — the way birdshot is rapidly cooled in water or oil — the easier solution is to add tin and antimony to the amalgam.

Figure 9: Incomplete mold fill.

Figure 10: Improperly filled casts can lead to malformed bullets.

Figure 11: Lead ingots.

Figure 12: Ingot tray.

An added benefit to the process is the lowering of melting point and reduction of drossing. For actual casting, various combinations of tin and antimony are used. Pure lead has Brinell hardness of around 5.0; each 1 percent of tin added increases it by 0.29–0.3. The main purpose of tin is to reduce the surface tension, improving mold fill. It also reduces the melting temperature of the alloy, getting as low as 361˚F at 63 percent tin content. Such a mix isn't commonly used: while harder than lead, it's not very dense. Thanks to their hardness, high tin alloys have good penetration despite low density. Since the velocity of such bullets falls off quickly, they make most sense for short-range uses where quick follow-up shots are important. Such alloys also work well for low-recoil target ammunition. Various alloys have different aging characteristics, with high tin content causing softening over time.

Every 1 percent of additional antimony increases hardness by 0.86–0.9. Ninety percent lead with 10 percent antimony will melt at around 480˚F instead of 621˚F. Typical hard bullet casting alloys contain between 0.5 percent tin and 2 percent antimony for BHN 11–12, and 15 percent tin with 23 percent antimony for BHN 28–30. With antimony melting point being fairly high at 1,167˚F, most ingots earmarked for bullet production already contain some proportion of it. Some also contain trace amounts of arsenic to make heat treatment more effective.

The empirically derived formula for best hardness is based on the chamber pressure: BHN = psi/(1280). So, a target load for .45 ACP can make do with BHN 16–18, while 30-30 Winchester would do better with BHN 30 and higher. Using excessively hard alloys would result in poor obturation, with gas blow-by and

Figure 13: (Left to right) Cast polymer coated 9 mm flat point and hollow point, swaged jacketed hollow point.

Figure 14: (Left to right) Cast 357 Magnum plain and polymer coated flat points, swaged jacketed hollow point.

excessive leading. Very soft lead fired at higher pressures would fail to be engraved by the rifling. Paper patching and, for higher velocities, polymer coating, metal plating, or jacketing, were developed to mitigate that problem. Polymer or metal "skins" allow dispensing with the lubricants typical of plain cast ammunition, reducing the amount of smoke from each shot.

Bullet lubrication appeared almost at the same time as the elongated modern rifle bullet. Having a greater bearing surface than with a patched round ball, cylindroconical projectiles used animal or plant fats to reduce friction and lead fouling. Conventionally lubricated bullets have an advantage for black powder shooters, as the lube makes powder residue easier to remove. With paper cartridges common from the 1830s to the 1870s, lubricants also helped waterproof the ammunition to some extent. Most long bullets have several grooves, one of which is used for crimping and the rest for the lube, which can be one of many substances of plant, animal, or petroleum origin. Dry lube, like graphite, is also an option. Upon firing, the bullet deformation and the gas pressure force the lubricant out of the grooves and into the rifling around the bullet. Some of that lubricant burns up upon firing, producing the characteristic smoke. Mainly for the reduction of that smoke, many bullet casters have gone to polymer coatings. Another expedient for reducing both the lube burn-off and the gas cutting of lead at the bullet base is the gas check, a thin ductile metal pod of copper, zinc, aluminum, or brass placed at the base of the bullet. With higher velocity cartridges, gas checks reduce lead fowling and can improve accuracy by preserving the integrity of the bullet base. Gas checks are cheaper and easier to apply than complete jacketing and, being applied at the base, do more to ensure stable exit from the muzzle than jacketing from the front with the base remaining exposed, as is typical of "full metal jacket" ball ammunition.

Polymer coating has the advantage of simplicity of application, low cost, and a variety of color options that permit color coding different loads. It reduces lead fouling, especially in polygonal rifled barrels. Softer than metal jacketing,

Figure 15: Polymer coated bullets on a drying rack.

Figure 16: 308win JSP next to polymer coated cast round nose.

polymer coatings permit velocities as high as 2,400 fps–2,500 fps, with less wear on the lands of the rifling (Figure 15). As with jacketed ammunition, polymer-coated bullets must be sized before they are loaded into cases. Unlike lubricated lead, polymer-coated bullets do not emit smoke on firing as there's nothing to burn off.

Originally, cast bullets were spherical because there was no way to ensure specific orientation during loading. The first spheroconical bullets had hollow bases that expanded to improve obturation. Soon thereafter, hollow point projectiles appeared. As velocity increased, harder alloys had to be used, so hollow point bullets were put into use to ensure expansion of projectiles. That was especially important for low velocity handguns. The standard 1890s Webley .455 "Manstopper" was an "H" in profile, chamfered just slightly on the front for ease of loading. The Hague convention of 1899 put an end to expanding military ammunition, and hollow point bullets largely went away until the 1960s.

For casting such shapes, removable pins were used. Without the pins, solid bullets resulted, and with them, hollow points and/or hollow bases. The same mold could produce either kind.

Figure 17: Hollow point punch.

Figure 18: Uncoated cast ball and hollow point .30 caliber rifle bullets.

Figure 19: Ball and hollow coated point bullets next to an uncoated one.

NOTES

NOTES

SCHOOL OF SDI FIREARMS TECHNOLOGY

Swaging

NOTE: The following chapters are heavily excerpted from Corbin's Handbook of Bullet Swaging No. 9, available from Corbin's website. If you have any questions or would like more information on any subject covered here, please go to the website at www.corbins.com/swaging.htm.

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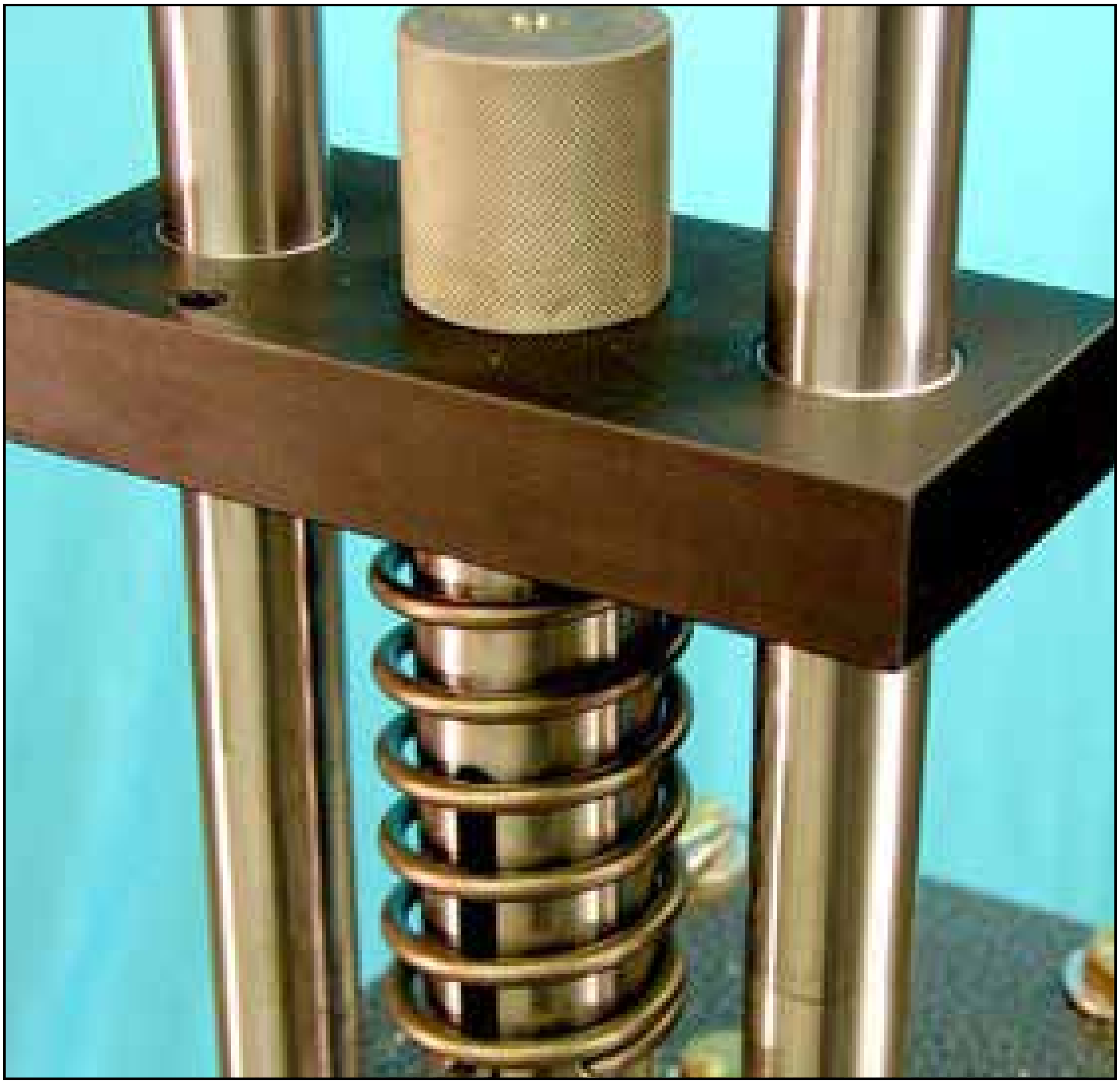
Chapter 4 - Introduction to Swaging



Introduction to Bullet Swaging

For over 40 years, Corbin Manufacturing & Supply, Inc. has been making the state-of-the art bullets often featured in gun magazines. Founded by president Dave Corbin, Corbin die-works has developed the equipment used by nearly every custom bullet maker in America today.

In fact, bullet swaging has played such a large part in the ammunition industry that there are currently more than 400 firms producing specialty bullets. These businesses are operated by people who took the step of putting their intense interest in firearms to work in a profitable and enjoyable occupation. Hornady, Sierra, Nosler, Barnes, Swift and a host of others actually owe their very existence to the concept of bullet swaging.

So, what is bullet swaging and how do you do it? What do you need to get started? How much does it cost? What are the advantages and drawbacks compared to casting or just buying factory bullets? Can you swage hard lead, make partitioned bullets, make your own jackets, make plain lead bullets or paper-patched slugs? The answers to most of these questions can be found in this course.

Swaging (pronounced swayjing) is actually so straightforward that you will be able to do it correctly after just a couple of tries. Because the principles involved in swaging are all the same, you won't need to be told specifically how to make every possible bullet — you will simply come to understand the basics and how to apply them. In fact, there are tens of thousands of different styles and shapes you can make, and not all of them are made in the same way. But with an understanding of the different presses and the dies that fit them, you will be able to make almost any configuration of bullet you can think of (Figure 1).

In the following chapters, you will learn the terminology used in bullet swaging and won't be confused by thinking a die is a punch or a punch holder is a die. You will understand that every swaging operation expands the components upward in size so that you won't try to put a larger part into a smaller hole — except when drawing down. You will know that in a swaging press, the die screws into the ram and the external punch fits into the press top in a floating punch holder. And you will understand that a smooth, stepless ogive requires a set of dies that includes a point-forming die, whereas a shouldered semi-wadcutter-style bullet can be made in a single die. If some of this sounds intimidating, don't worry — all these things will become familiar before long.

And once you've completed this course, you will have gained a solid understanding of what swaging is, how it compares to other bullet-making processes, and how to utilize the equipment and materials available to begin swaging your very own custom bullets.

Figure 1: *1 in. diameter, .998 in. is the 4-bore black powder elephant cartridge.*

What is Bullet Swaging?

Bullet swaging is the process of applying extremely high pressures (from 15,000 psi for soft, unjacketed bullets to as high as 150,000 psi for solid copper bullets) to materials contained in a very tough, extremely well-finished die, so that the material will flow at room temperature and take on the shape of the die and the ends of the punches.

Figure 3: Luber/Sizer.

SWAGING VERSUS CASTING

You recently learned about the process of casting, which is melting metal and pouring the molten liquid into a split mould, letting it cool and shrink, and then opening the split mould halves so that the frozen bullet metal can drop out. Casting involves a lot of time and introduces quite a few potential sources of inaccuracy, but it works reasonably well within a limited range of capabilities. You have to have a lead pot and a supply of lead, a mould and mould handles, then a lubricator and sizer machine to prepare the bullets (Figure 3). The sizer machine needs sizer dies and base and nose punches to fit the shape and caliber of bullet. It also requires lubricant to apply to the bullet.

In contrast, a swaging die runs at room temperature and does not contact hot metal. It flows the metal under tons of pressure, squeezing out all air pockets and voids (Figure 4). The bullet takes its shape and finish from the diamond-lapped

Figure 2: Casting pot and tools.

Figure 4: Swaging a lead bullet.

hardened surface of the die. The die is not split, but is a solid tube or cylinder with thick walls to hold the pressure. The bullet material goes in one end and is pushed back out the same way. Two precisely fitted punches seal both ends of the die. One moves in and out to load material and the other acts as an ejector.

The problems associated with heat expansion, swinging split section alignment, and the time required to prepare are absent or minimized with swaging. In addition, the die can make a wide range of weights depending on how much material you put into it. A mould makes approximately one weight because you must fill it to make a bullet. These are just a few of the differences between casting and swaging.

There is one thing you can do more quickly and easily with casting than with swaging and that is forming a lead bullet with grooves for lubrication. With swage dies, the bullet goes in and then comes back out the same hole in the die. If you think about that for a minute, you will understand that it would not be possible to swage a groove into the side of the bullet and then push it back out of the die. The die would have to be "split" like a mold. While this is possible, it is not cost-effective.

Fortunately, you can roll grooves into a swaged lead bullet (Figure 5) with a grooving tool made by Corbin, or use better bullet designs or surface lubricants that eliminate the need for grooves. You can also swage jacketed bullets so that separate lubricant is not required.

Corbin equipment can swage bullets from .123 diameter up to about 1 in. diameter (.998 in. is the 4-bore black powder elephant cartridge, for example). The bullet can be an airgun pellet, a swaged round ball, a shotgun slug, a fragmenting shot, a powdered, metal-filled, jacketed pistol bullet, or a partitioned or multi-jacketed projectile. It can be made of pure lead, various lead alloys, or powdered metals pressed together with or without a jacket. It can be a conventional

Figure 5: *Grooves in a lead bullet.*

jacketed bullet with a lead core, with or without other inserts such as penetrators or light plastic fillers to shift the center of gravity and create fast, light, but long projectiles. In short, just about anything that can be launched from a small arm, be it airgun, shotgun, rifle or pistol, and some kinds of machine guns and cannons, can be swaged and is considered a bullet.

SWAGING VERSUS DRAWING

In swaging bullets, you will always be putting a smaller diameter object (lead, jacket, or a combination of both) into a slightly larger die cavity or hole. Each step in swaging increases the diameter of the components until they reach the final diameter in the last die. Swaging never reduces the diameter. You will only have stuck bullets and hard ejection if you try to push a slightly larger part into a slightly smaller hole. This is the difference between swaging and drawing. You never swage anything "down." You never draw anything "up."

In drawing, you do push a larger part through a smaller hole to reduce the diameter. This kind of die is a ring, not a cylinder closed on one end. The jacket or bullet that you are reducing is pushed through the ring and is decreased in diameter when it comes through the other side.

Figure 6: Corbin Precision drawn/trimmed bullet jackets.

JACKETS

A jacket is the "skin" of a bullet (Figure 6), usually made of copper or a copper alloy with zinc (most commonly 5 percent to 10 percent zinc). Jackets can be used or not, depending on the bullet design. A jacket isolates the lead core from contact with the barrel and allows the bullet to be shot much faster without friction melting the core and smearing it in the barrel, which is called "lead fouling." Enough of that spoils the accuracy and is hard to remove. Jackets will be discussed in detail later.

The right way to swage bullets is to use jackets that fit easily into the die by hand and lead cores that are small enough to easily drop into the jacket. Jackets have some wall thickness, of course, generally from 0.015 in. to 0.035 in., although there is no rule that says you can't make much thicker jacket walls if you want them. To determine the diameter of the lead core that fits inside, you must subtract two times the wall thickness from the caliber and then subtract an additional five to ten thousandths of an inch to allow for easy insertion, tolerances in the lead wire diameter, and the fact that you may have two or three steps with a small amount of expansion in each to get to final caliber.

BASIC SWAGE DIES

There are two basic designs of swaging dies made by Corbin. All the specific styles of dies are patterned after one or the other of these basic designs. One design is a cylinder with a straight hole through it (Figure 7). The other is a cylinder with a semi-blind hole, having the shape of the bullet except at the tip where there is a tiny hole (.052 in. to .120 in. is a typical range) fitted with a strong piece of tempered spring wire (Figure 7A).

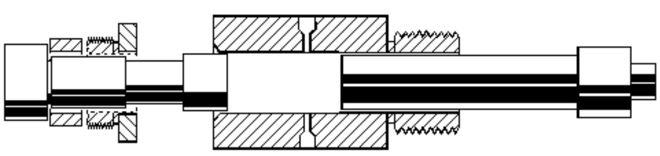


Figure 7: *Core swaging die.*

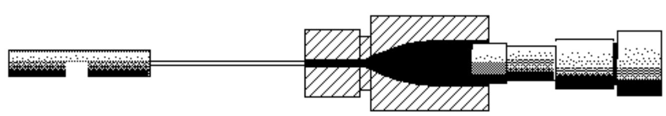


Figure 7A: *APF (point-forming) die.*

Figure 8: Examples of nose shapes.

The first design can be used for any sort of operation where two punches can form the desired shape on the end of the enclosed materials. An example would be a "Core Swage" or "CSW-" die, which takes in a piece of cut lead wire or cast lead pellet (the "core" of a bullet) and gives it a precise diameter with smooth flat ends and extrudes off whatever surplus lead there might be for the weight you desire. Three little bleed holes in the sides of the die, at 120° intervals, allow surplus lead to spurt out as tiny wires, which are sheared off during ejection. Core swages are used to make the lead filling (core) a precise weight after it has been cast from scrap lead or cut from a piece of lead wire.

This kind of die can also be equipped with a punch having the shape you want for the bullet base, and with another punch at the opposite end having the shape you want for the nose (Figures 8 and 9). Both shapes will be in reverse: the bullet nose is formed in a cavity in the punch, and a hollow base bullet would use a convex or projecting punch. This is what is called a "Lead Semi-Wadcutter" or "LSWC-" type of die. That doesn't mean you have to make a particular shape that you know as a semi-wadcutter bullet. Rather, it's just a short way of saying you could do that or make any other shape that has the entire nose formed — right out to the full bullet diameter — by pushing the lead into a cavity in the end of the nose forming punch.

The core swage die generally has flat punch ends and a diameter far less than the final caliber. It is used to prepare the lead core to fit inside a bullet jacket in most cases. Keep in mind, though, that you don't have to use a jacket — you can just swage the lead core to final shape in the next die if you desire to make a high-quality lead bullet, such as a paper-patched or Gase-Guard style. Lead bullets can be made either in one die (the LSWC) or in two dies (the CSW and CS types, or the CSW and PF types). Jacketed bullets generally require at least two and sometimes three or more dies.

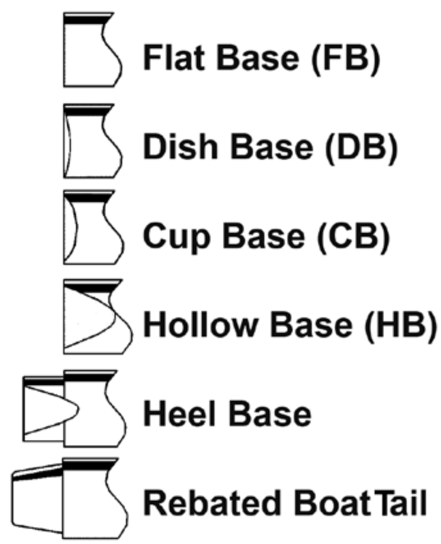


Figure 9: Examples of base shapes.

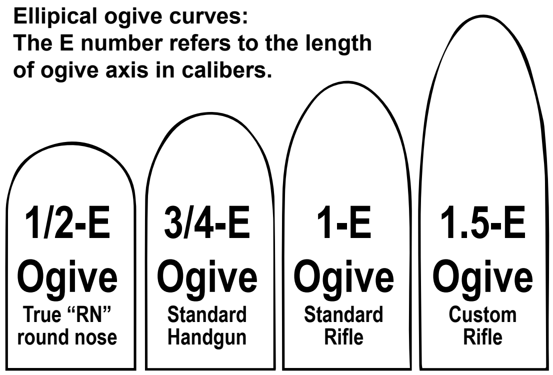


Figure 10*: Two different graphics of ogive examples.*

The purpose of the lead tip forming die is to finish the very end of a pointed (spitzer) bullet, and it isn't normally used for semi-wadcutter or large lead tip bullets. It looks just like a core seater, but the bore diameter is slightly larger than the final bullet size, whereas the core seater diameter is just slightly smaller than final bullet size. The internal punch of a lead tip die is designed with a cavity to reshape the extruded lead tip of a sharp-pointed rifle bullet so that it looks perfect. It cannot form the entire ogive because the edge of the punch, which must withstand tons of swaging pressure, cannot be paper-thin and survive.

This section began by discussing two general die designs, one with a straight hole through it and one with a semi-blind hole. This second kind of die came about because, try as you will, there isn't a reliable way to make a straight-hole die form a smooth curve from shank to tip. (The bullet nose curve is called the “ogive” (Figure 10), pronounced oh-jive, and comes from the French “ogee,” which is the bullet-shaped curve over a doorway). That punch with the cavity machined in the end must have some thickness at the edge, and this edge will impress itself on the bullet to make a shoulder.

In referring to a “semi-blind hole,” it is meant that the hole in the die is not straight through the die, but is shaped like the bullet itself. At the tip is a very small punch to push the bullet out by its nose, and this punch is retracted a short way up into its little access hole so there is no possibility of the bullet material pressing against it (which might otherwise bend the small diameter punch under those tons of pressure).

The “Point-Forming” die, which is abbreviated “PF,” accepts either a lead core or the seated lead core and jacket combination swaged in the core seat die. A full-diameter external punch shoves the material into the point-forming die. The material is compressed inward in the small end of the die, giving the bullet its smooth curve or angled nose (the ogive). The pressure also expands the shank slightly to final diameter.

REBATED BOAT TAILS

What about bevel bases or boat tail bullets (Figure 11)? Those also have the bullet smoothly angled away from full shank diameter. So, they also require a variety of the point-forming die that is used to shape the base instead of the nose. The boat tail bullet has largely been

Figure 11: Different calibers of rebated boat tail bullets.

replaced in swaging circles by the superior "rebated" boat tail, abbreviated "RBT" as opposed to the more conventional "BT" for boat tail.

Why are most custom bullet makers using the RBT instead of the standard boat tail base? There are three reasons:

1. A regular boat tail bullet tends to act like the focusing nozzle of a water hose during the moment it emerges from the barrel. Hot powder gas rushes around that boat tail angle, flows up the sides of the bullet, and continues in a smooth, laminar low pattern right around the front, where they break up into turbulent flow and make a fireball of gas — right in the path of the bullet! You can get up to 15 percent increased dispersion at the target just from the buffeting the bullet gets by shooting through this ball of gas. A flat base bullet deflects most of the gas in a circle of fire, expanding rapidly out from the bore with a clear space directly in front of the bullet. The edge of the flat base acts like a "spoiler" to break up the laminar flow before it can get started. And so does the sharp shoulder on a rebated boat tail! How does a 15 percent improvement in accuracy sound as a benefit of using the RBT design?
2. The boat tail bullet tends toward more bore erosion than the rebated boat tail because gas pressure on the boat tail tends to peel it back away from the bore and lets some gas up past the bottoms of the rifling grooves, where it cuts the bullet and the barrel like a hot cutting torch. The rebated boat tail has a 90° shoulder that takes the pressure parallel to the bore, instead of at a compression angle away from it. How does increased barrel life strike you as a second reason for using RBT bullets instead of the regular BT style?
3. The tooling lasts longer, costs less to build, and is more easily built to high standards of precision. Corbin Manufacturing has perfected a method of using two dies, called the "Boat tail 1 in. and the "Boat tail 2 in. dies, as a set, to produce a virtually flawless and highly repeatable rebated boat tail. Instead of making the boat tail angle so it can be higher on one side or at a little slope like some of the factory production you see today, this system guarantees that the boat tail will start precisely at the same point on one side of the bullet as it does on the other, every time.

With all these benefits, there is hardly any reason to make standard boat tail dies these days. The RBT has been proving itself all over the world for more than 30 years to those who are wise enough to give it attention. However, if you were to ask what base design would generally be recommended for jacketed bullets with a range of up to 250 yd., there would be no hesitation in saying a flat base. Rebated or not, a boat tail does not give you superior accuracy in and of itself. It gives you less base drag.

BEVEL BASES

Bevel base bullets are made by seating the core in a special "point-forming" die instead of the usual core seating die. The jacket is put into the

die, and the lead is pushed into the jacket. The base of the bullet flows down into the short, beveled section of the die (it can't be a punch cavity, remember, because the edge of the punch would cut the bottom of the jacket). You could also seat the bullet in a normal core seating die, and then reform the base in this die, but it would be redundant.

A lead bevel base bullet could be made in two steps: swage the lead core using a rather large, almost finished diameter core swage, and then push the bullet into the special point-forming die backward, using a nose punch as the external punch. In fact, any lead bullet with a smooth ogive (no semi-wadcutter shoulder) can best be made by using first a CSW die to adjust the weight, and then a PF die to form the ogive. Without a jacket, you don't need the CS die, the purpose of which is to expand the core into the jacket and form a tight, parallel shank.

***Figure 12:** LSWC-1-M, a lead semi-wadcutter die.*

DIES CLASSIFIED BY PRESS TYPE

So far, the basic design of bullet swage dies in regard to their function has been discussed. But there is another category for classification of swage dies, and that is by the kind of press used to operate them. Swaging dies can be designed to operate in a reloading press (with severe limitations on pressure and precision), or in a number of different models of bullet swaging presses, both hand and hydraulic/electric powered.

The classification by press type also defines the die thread and diameter. The last letter in the catalog number identifies this classification. Dies with a catalog number ending in -R (such as the PRO-1-R) fit a standard ⅞ in. x 14 thread reloading press with an RCBS-type button shell holder ram. The die screws into the press head like a reloading die. The external punch slips into the T-slot of the ram. You do not also use a shell holder, since the punch base is made to simulate one.

Dies with a catalog number ending in -M fit either the discontinued Silver Press, or the current S-Press. They are being phased out of stocking status in favor of the -S dies, which are larger and stronger and fit the current S-Press or its predecessor, the Series II press (discontinued). However, the company will continue to make them on special order, just not as a stock item. The -M dies have a ¾ in. diameter main body, a thrust-adsorbing shoulder, and a ⅝ in. x 24 threaded tenon. The die screws directly into the press ram, and the external punch is held in a Corbin floating punch holder in the press head. An example of an -M-type die is the LSWC-1-M, a lead semi-wadcutter die (Figure 12).

The current type-S dies fit the discontinued Series II press or its replacement, the S-Press (Catalog number CSP-1). An example of a set of -S dies is the FJFB-3-S, a three-die set (Figure 13). The -S dies have a longer and larger diameter body than the -M type, being 1 in.

Figure 13: FJFB-3-S, a three-die set.

diameter. By using the same 1 in. x 24 threaded tenon, the thrust shoulder is wider and thus spreads the force over a wider area (the top of the industrial chromed alloy steel ram in Corbin presses). This also means the S-Press can accept both the older -M dies and the current -S dies. A bench-type hydraulic powered version of the S-Press, called the "Hydro-Mite," also uses -S dies.

Finally, the type -H dies are made to fit the Corbin Hydro-Press, or the Mega-Mite hand press. These dies are typically made in a 1.50 in. diameter, with a length appropriate to the maximum bullet weight to be produced (up to 3 in.). The thread tenon is made with a 1 in. x 12 in. thread (meaning 12 turns per inch) to screw directly into the press ram. The external punch fits into the huge FPH-1-H floating punch holder in the press head. A "positive stop" FPH-2-H punch holder is also available for extreme high precision weight control.

Swaging Principles

1. Always swage "up," never "down." Swaging down is a contradiction. You "draw" down by pushing something through an open-ended ring die, like the JRD-1 jacket drawing die (Figure 14) or BRD-1 bullet reducing die. Drawing makes the part smaller in diameter and longer. It can also cause separation of the core and jacket if done to excess. Swaging makes the part shorter and larger, and tightens the grip of the jacket on the core.

2. Pay attention to the instructions. If there are special written notes with your die, they are important because they modify or improve the general instructions and replace them. If there is a difference between specific notes sent with your set of dies and anything published in general (as in this book or in general printed literature), follow the special written instructions in any respect where they may differ. Swaging is partly an art, and various materials or sizes may react differently to the same general kind of operations.

3. Use the right terminology! It cannot be stressed enough how important it is to read what you have before you start to use it, and then order the right part numbers and names of parts. People call the external punch everything from a "pin" to a "ram" to a "die" to a "die punch." If you order it wrong, you get to pay a restocking fee; or, if it is custom made for you, then it may not be returnable. A die is the vessel or cylinder that holds the material. A punch fits into the end of the die and pushes on the material. A pin is part of the pivot system of the press, or the wire ejection pin that fits into a point forming punch. A ram is the moving steel drive component of your press into which the swage die screws. There is no such thing as a "die-punch" or a "punch-die." Putting terms together to suit yourself just confuses everyone.

4. Use the right materials! A set of dies made for a specific jacket, a certain lead hardness, or a certain alloy and size of copper tubing, may be able to work with other materials but probably not without adjustments to the punch and/or die dimensions and possibly not without developing differences in technique. Nearly all problems with broken dies and stuck parts or improper sizes come from the use of materials other than those used to develop the tools. Hardness, grain, and dimensions make a huge difference in your success.

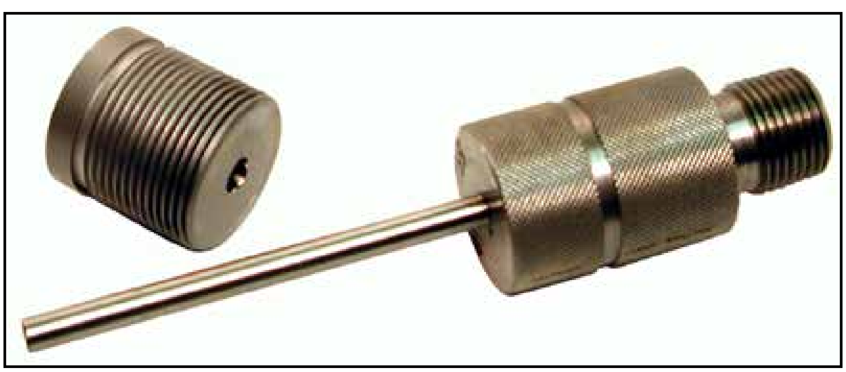


Figure 14: JRD-1 jacket drawing die.

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Tubing Jackets

Before you can make a jacketed bullet, you need the jacket. The jacket wall thickness, length, and size determines the dimensions and sometimes even the number and type of other dies you will be using. The issue of what jacket you plan to use comes first, assuming you are using a jacket, of course. Not all swaged bullets need a jacket. Paper-patched, lead, and other types will be discussed later.

You can buy some sizes and lengths of ready-made jackets (the cups or empty skins for the bullets). Corbin offers the high precision Versatile Benchrest VBTM jackets in popular rifle calibers, and nearly all standard calibers of handgun jackets. Bullet jackets are from .001 in. to .005 in. smaller than the caliber, so they can be expanded upward when you insert and seat the lead core.

Corbin makes two different systems to form your own bullet jackets: one system using tubing, and one using flat strip. Tubing dies cost less and fit more kinds of presses, but strip jackets have the accuracy edge and can be made with greater control over the wall tapers and thickness. Corbin offers deep-drawing grade copper strip in 5 lb. bundles of cut sections (typically 2 ft. pieces), and in 50 lb. pancake coils with a 16 in. center, which fit on their automatic uncoiler for automatic feeding.

Corbin also offers supplies of copper tubing in ¼ in., 5⁄16 in., ⅜ in., and ½ in. diameters from stock, and nearly any diameter on special order. All calibers from .224 to .512 can be made with the stock sizes. Jacketed shotgun slugs can be made with ¾ in. tubing, and 1 in. Gatling or 4-bore (.998) bullets can be made with 1 in. tubing. The company does not stock these larger sizes but by the time the dies are ready, a special order would be ready for you.

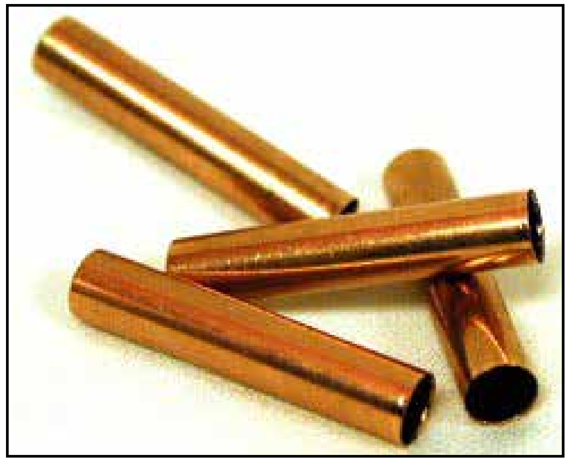

Figure 15: Copper tubing.

For big game hunting, the tubing jacket may have the edge since it is easier to build thicker-walled, tougher jackets with tubing (after all, the deep drawing operation is done for you in tubing and all you have to do is round over one end and adjust the diameter in a draw die). Jacket drawing from strip can be done easily in a hand press only for the shorter jacket lengths because punching out a disk and turning it into a cup requires a lot of power early in the stroke. Hand presses generate almost all their power at the end of the stroke. Hydraulic presses are used for rifle jacket lengths in order to get full power at the start of the stroke.

COPPER TUBING JACKET MAKER SETS (CTJM-1-S, AND -H)

You can make jackets from copper tubing or almost any other metal, but copper, aluminum, brass, and mild steel are the most practical to use; and of these, copper works best for most shooting needs. To do this, you could use copper water tubing (yes, the same kind used to hook up wash basins), boiler tubing, or refrigeration tubing. Corbin has precision drawing grade tubing available also, if you want "good stuff" for testing.

Regardless of the size or type, you would cut the tubing to length, deburr one end, put the piece over a precision punch and round the end over in the proper diameter end-rounding die (looks like a blunt point-forming die), anneal the tube, draw it to smaller diameter, and then flatten the end with a special punch in your normal core seat die. All the tools you need to form the cut tubing pieces are included in the CTJM-1 tubing jacket maker, with the exception of the tubing saw to cut the tubing to length, and the proper core seating die to flatten the end of the tubing (or to form the boat tail base). The core seating die (or boat tail base former die) is part of the bullet swage set, so it is normally assumed that you have this die already.

The tubing jacket maker set will include whatever additional components are needed in order to seat the core into the jacket. For example, if you order the tubing jacket maker for .458 caliber, Corbin will provide a proper size core seating punch to fit the jacket for a given weight of a flat base bullet. However, if you plan to make a rebated boat tail bullet, you might need to purchase one additional punch — an adjustable length core seating punch. This is a shouldered punch, which presses against the end of a given length of jacket and keeps it from extruding forward while the lead is being seated. Sometimes a RBT design will cause the copper tubing to extrude forward, which not only elongates the jacket but stretches and thins it at the base, where it may separate within the die. Using the adjustable length core seating punch holds the jacket in place and prevents this from happening.

TUBING JACKET ADVANTAGES OVER DRAWN JACKETS

The advantages are (1) the tooling is lower cost; (2) the number of operations is relatively small and easy to learn; (3) tubing is fairly low cost in modest quantities compared to buying large rolls of strip material; and (4) the process makes excellent bullets for big game shooting.

In a Corbin hydraulic-powered press such as the CHP-1 Hydro-press (Figure 16) using the -H family of high-pressure dies, you can completely close the base so no hole appears. In the -S family of hand press dies, which fit the Corbin S-Press CSP-1, or when using an -H die in the Mega-Mite CSP-2 hand press, you usually cannot generate enough pressure to completely

Figure 16: *CHP-1 Hydro-press.*

close the base, so a tiny hole remains, but it is far smaller than most military open base bullets and causes no problem.

Tubing jackets are most often used with hunting bullet designs, and nearly all commercial bullet makers today use Corbin Core Bond to create a bullet that will not shed its core, and can be shot "inside out" without losing much of its total weight. Core Bond is inexpensive, fast, and works much better in actual big game hunting than a partitioned design. The entire core is secured to the jacket, rather than just protecting half of the core.

Corbin is aware of many amazing and possibly lifesaving performances from bonded core bullets using their Core Bond process as compared with other designs that failed. There is no doubt for Corbin Manufacturing that, given the choice, every bullet fired at a dangerous game animal should be a bonded core design.

DISADVANTAGES OF TUBING JACKETS

1. The walls are straight, rather than tapered, so that without special operations the jacket will not be the "controlled expansion" type.

2. Tubing jackets larger than .257 caliber generally are not practical to make below .030 in. wall thickness. Sometimes you can get .025 in. wall tubing, but it is harder to find and doesn't always form, in every caliber or shape, without buckling.

3. It is not practical to build precision benchrest grade bullets using readily available tubing. This is not to say tubing jackets are "inaccurate," but only that a deep drawn jacket can be made with closer tolerances given the materials available on the market today. Tubing jacket bullets can, and have, set match records, but they probably will never set high level competitive benchrest records. On the other hand, they certainly do bring home a lot of big game every year where the thinner and more brittle drawn jackets fail and let it get away!

4. Tubing jacket makers do not lend themselves to automatic production as easily as strip jacket makers. The initial step in making a tubing jacket is to cut a piece of tubing to a specific length. From this point on, it is handled as an individual component. Strip can be fed into a stacked or progressive die system that allows some of the operations to be done to the jacket in a continuous feed procedure, as the strip itself provides some of the conveyance of the forming jacket. On the other hand, there are less steps involved in making tubing jackets than in forming strip into a jacket.

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Drawn Strip Jackets

A second form of jacket making uses flat strip instead of tubing and is the method used by the mass producer of bullets (Figures 17 and 18). Strip material generally costs less per bullet than tubing and lets you make exactly the wall thickness, wall taper, and length of jacket desired. In a hand press, the jacket must be kept relatively short, generally under ¾ in. But in Corbin's CHP-1 Hydro-Press, you can make 20 mm jackets, .50 BMG jackets, and jacketed 12-gauge shotgun slugs. You also can make smaller calibers and jacket walls thicknesses, everything up to virtually solid material.

Changing calibers or operations is quick and simple in comparison to a punch press. Fifteen hours might possibly give you enough time to get a punch press retooled for another caliber, including the tedious testing and adjustment period. Comparatively, you could easily set up the Hydro-press for jacket making in under 20 minutes. Five minutes would be slow for changing calibers.

Figure 18: JMK-1-H Jacket Maker.

COPPER STRIP

Copper strip (Figure 19) can be purchased from Corbin or from over 200 copper mill outlets in the United States and Canada. Many of the large copper mills have outlets around the world. Olin and Revere share space in *Corbin's World Directory of Custom Bullet Makers* with the makers of precision brass, gilding metal, German silver, bronze, and aluminum tubing and strip.

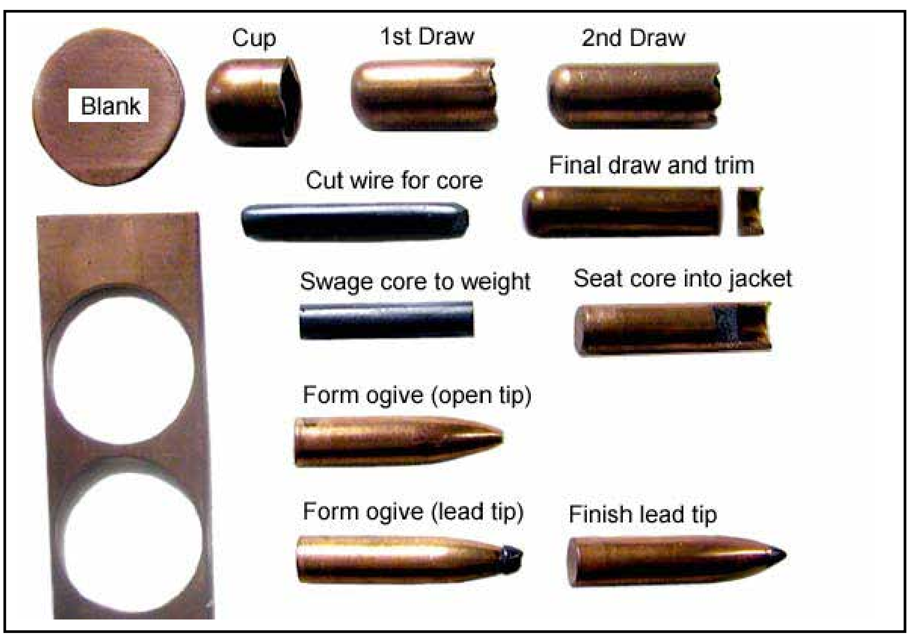


Figure 17: Example of how a jacket is made.

Figure 19: Copper strips.

BASE-GUARD BULLETS

Bullets can be swaged without jackets, using just the lead, or you can swage jacketed bullets, but there is a hybrid design that reduces cost and increases production speed while extending the usable velocity range beyond a lead bullet. In fact, this special design, called the "Base-Guard," permits you to shoot pure, soft lead bullets at up to 1,400 fps — without fouling the bore or using any lubricant, and even cleans fouling from your bore as you shoot (Figure 20)!

The metal used did not matter — barn siding, tin cans, shim stock brass, and copper jacket material as well as zinc were used. In fact, copper seemed to work better. The main thing was the difficulty in holding such tight diameter tolerances on a low-cost part. The high precision disks were too costly to make, but they worked fine. They worked better than a half jacket on handgun bullets and on .45-70 rifle bullets. The problem was how to make them almost perfect zero tolerance diameter and also how to form the sharp edge without a lot of expense. If the disks were cut slightly oversized and made cone shaped, it was discovered the diameter would effectively be reduced and easily drop into the swage die. But when pressure flattened the conical disk again, it would grow back to original size! The die wall would stop the growth, and any extra material would be forced to extrude forward, into the soft lead bullet, just below the edge. The other side would be backed up by a hard steel punch, blocking any extrusion in that direction.

By making the disks conical and slightly over caliber before the cone shape is applied, the cone will drop into the die, grow to full diameter plus a burnishing tool edge, and there will be absolutely zero tolerance between the diameter of the bullet (the lead part) and the diameter of the base disk! It could be no other way: both parts receive their final diameter from the swaging action, within the same die, at the same moment.

One of the special advantages of not using lubricant is there is no puff of lubricant smoke, which means the Practical Pistol shooters do not have to try for double-taps while looking at an obscured

Figure 20: Examples of Base-Guard separate and installed on bullets.

sight picture on the second shot. When you are firing two shots that come so fast they sound like one, lubricant smoke can be a problem.

There are two big advantages of the Base-Guard. The first is that you can make the bullet in one, or at most two, strokes of the press. Second, the cost is almost the same as a cast bullet without the disadvantages of lubricant, extra handling, hard lead alloys, and rejects. Corbin has made 400 bullets in just under an hour, including cutting the lead wire, swaging the bullets and making the Base-Guards!

Base-Guards are superior to gas checks and half jackets in three ways. First, they cost about half the price of gas checks and a quarter the price of half jackets. Second, they turn with the rifling on their central axle instead of being pinched against the bullet, so if the bullet slips in the rifling, the Base-Guard keeps tracking and seals the gas. Third, they scrape fouling out of the bore, instead of ironing over it repeatedly.

Draw Dies

Drawing dies have a hole all the way through and they fit into the press head. To make the part smaller in diameter, push a jacket or bullet through them, in one side and out the other. Since the die screws into the press head, the re is really no difference in the $\frac{5}{8}$ in. x 14 threaded die body for type -R or type -S sets. The only difference is the punch because a reloading press (-R) uses a T-slot ram and Corbin presses use threaded rams ($\frac{7}{8}$ in. x 24 tpi for the S-Press).

The -H dies utilize tougher materials that stand up under greater force and speed. Part of the reason they cost more is because of the additional time it takes to form and heat-treat this material. You can adapt a -M or - R draw die to a hydro-press, but it is not as economical as it may seem due to the possibility of breakage and less efficient use of the available stroke for alignment and guidance of the components.

Figure 21: Corbin's popular KIT-224R for making .224 bullets from 22LR fired cases.

Type -R dies are only available in the standard design because it is not practical to use a reloading press for high precision or high production work. A reloading press would be incredibly hard to use for production work (because of hydraulics) and to attempt to use one for high precision jacket drawing of the benchrest class would be an exercise in futility.

RFJM-22 -R, -S, -H (RIMFIRE JACKET MAKER, 224 CALIBER)

One of the most popular tools from Corbin is the Rimfire Jacket Maker set, which turns fired .22 cases into excellent jackets to make .22 centerfire bullets. RCBS, Speer, Hornady and many other firms got their start by doing just this. It can still be done today, and with the price of bullets, it is more popular than ever (Figure 21).

Fired .22 short cases make great 40-grain Hornet jackets. Fired .22 Long or Long Rifle cases make the standard .705 in. -Long 52- to 60- grain open tip or small lead tip bullets for all flavors of centerfire .22 cartridges, from the .222 to the .225. Some shooters don't realize that all modern .22 caliber centerfires, including the 5.56 mm, actually use the same diameter barrel (a nominal .224 bullet size fits them all).

The .22 high velocity loads, such as the "Stinger," use a case slightly longer than the standard Long Rifle, which will produce a little heavier bullet; 65- to 70-grain .224 bullets can be made using these for jackets.

The process is simple. First, wash the fired cases to remove grit. One preference is to boil them in a mixture of water and some detergent, plus a little vinegar to help restore the shine. Next, pour off the water and spread the cases out on an old cookie sheet. Finally, turn on the kitchen oven and heat the jackets quickly to drive off the water.

Soon after there will be a tray full of clean, dry cases. Take them out and put the jacket maker die in the press. The die itself is the same for both reloading presses and for the Corbin S-Press. The -R differs from the -S version only in the punch.

In the reloading press, the punch has a T-slot head or button, like a shell-holder. In the -S version, to fit the S-press, the punch has a kind of die body attached that screws directly into the ram. The die screws into the press head in all versions.

Use a little Corbin Swage Lube on your fingertips and give the punch a quick wipe of lube, then pick up a case and put it over the punch tip. Adjust the die so it is very high in the press threads. Raise the ram carefully. The rim of the case should just barely start to go into the die as it reaches the end of the ram stroke.

Lower the die until this point of adjustment is reached, and then lower it just another quarter turn or less. Lower the ram, as necessary, to adjust the die and then raise the ram. Little by little, the point where the rim is ironed out cleanly will be found, leaving no ridge behind. Then continue to carefully adjust the die downward, until the jacket can be pushed through the tightest part of the die and out the top with one smooth but powerful and rapid stroke.

Do not operate the press with the die so low that it takes significant effort to push the cases through. This is not necessary and will only strain the bench mountings. A firm one-hand push will do the job in a single pass.

These little jackets represent a lifetime of free components, so it is worth spending a little time to learn the fine points. Once the jackets have been drawn, they may need to be annealed. One fine point is that the annealing temperature can be critical. If a wide open tip or a large lead pointed bullet is made, it may not have to be

annealed at all. If an attempt is made to make a small open tip bullet, or even a small lead tip, it is possible that the end of the bullet folds over with a little flap of metal instead of drawing to a smooth curve.

This is a sure sign that the jacket material is not annealed sufficiently. Actually, annealed may be the wrong word because that implies a dead, soft condition. Just soften the brass to a lesser degree, more of a stress relief heat treatment. If the cases overheat, they will discolor and may become rough on the surface. They can always be heated a little more, but damage from overheating cannot be undone. Some people use a tuna can floating in a molten lead pot to hold the cases for annealing. One option is to use a self-cleaning oven or a propane torch with a fishtail flame spreader and just heat the cases until they are barely red in a dimly lit room. It only takes a few seconds to get them that hot. A small group of twenty or so can be done at one time.

It is possible to skip this step, but make one bullet all the way to completion before seating all the lead cores in those jackets: it may need to be heated a little more. If that happens, the seated cores make it harder to do (but not impossible).

Commercial bullet jackets for .224 caliber are usually made from strip that starts out 0.026 in. to 0.030 in. thick, with walls that taper forward to perhaps as little as 0.012 in. to 0.015 in. at the mouth. But the greater part of the jacket wall is more likely to be from 0.020 in. to 0.026 in. thick. This means that the free .22 rimfire jacket is about half as thick, in general, as the commercial bullet jacket. It is also made of a higher zinc content brass, having nearly 30 percent zinc as compared to the 5 percent to 10 percent zinc in the commercial bullet jacket. This means it is slightly harder but more brittle, as well as thinner.

Figure 22: *Examples of bullets made from 22LR fired cases.*

These factors result in an excellent varmint shooting bullet, with little or no ricochet odds (when the thin, brittle jacket hits the ground, it usually explodes or pops open into a four-pointed "star" all the way to the base, even at modest speeds). But the speeds must be kept relatively modest, or else the thin jacket will come apart in flight. Corbin usually recommends that a velocity of 3,200 fps or less is maintained. Some people shoot faster and get away with it. It probably depends on the depth and sharpness of the rifling in a given barrel, and whether it cuts into the thin jacket or irons the grooves without weakening the jacket even further.

A fired .22 case made into a bullet is actually less likely to cause fouling than a commercial jacket. It has more zinc, which makes it harder, slicker, and tougher, and less likely to come off in the bore. Accuracy is well known by now. Some brave souls even won benchrest matches with fired .22 case bullets. If high grade brass is selected and sorted into lots, fired from the same gun (such as those that might be picked up at an indoor target range after a finished match), then it is almost equivalent quality as

the best commercial jackets, including jacket run-out. Ely Club ammo used to be the best for quality rimfire case jackets.

Bottom line: rimfire case jackets are easier on the barrel, just as accurate, and probably foul less than commercial jackets. Their main drawback is that they are thin and therefore cannot be driven so fast. Likewise, their thinness makes them unsuitable for big game. But most people are not that good of a shot or a stalker to allow use of a .224 for big game and still able to call themselves a good sportsmen.

Their advantage over commercial jackets is cost: they are free. Making a good varmint bullet that blows up like it was going 4,000 fps when it hits at a mere 3,000 fps, then that is another advantage — not to mention how much fun it is to out-shoot others who paid good money for their bullets and refuse to believe that anything made from free materials could possibly work as well or better (Figure 22)!

Making Lead Cores

Lead is the most commonly used core material for bullets. What is a core? The material that fills up the jacket is a core, but even if the jacket does not get used, the piece of lead that will form the swaged bullet is also called a core. Swaging requires that the core is prepared so that it will fit inside the swage die. A huge billet of lead cannot be shoved into the die, but the lead can be melted and cast in a multi-cavity "core mould" to form the right diameter and length of ready-to-swage cores; or the lead wire can simply be purchased. With Corbin power presses and optional extruder die, lead wire can be made.

LEAD WIRE (LW-10)

Lead wire in 10 lb spools, LW-10, is available from Corbin in sizes from .100 in. to .430 in. diameter (Figure 23). Lead wire is by far the most convenient and timesaving way to produce bullets. It eliminates all of the risk from hot lead. Simply chop the lead wire into the correct lengths using a tool called a "core cutter." Since Corbin lead wire is 99.995 percent pure, it can be used as a sample for hardness testing (Bhn 5.0). It is provided in single rolls, or in case lots of four rolls for a discounted price (provided the four are the same diameter).

Lead wire comes in .100 in., .125 in., .170 in., .185 in., .218 in., .247 in., .275 in., .312 in., .340 in., .365 in., .390 in., and .430 in. diameter. It is provided in pure form only, not as alloys. Alloyed lead can be cast, but it is more difficult to extrude. In most cases, there is no advantage to hard lead for swaging. Soft lead is more dense, expands better without breaking apart, and bonds very well to the jacket.

FOUR CAVITY CORE MOULD (CM-4A)

If casting lead cores is preferred, the CM-4a Four-Cavity Core Mould can be adjusted for any practical weight of core by setting the displacement of four pistons in their matching, honed cylinders. It is rather like a straight-line automobile engine: the sprue cutter is a long handle similar to the engine head; the four pistons slide up and down inside of matching cylinders to eject the cores as soon as you rotate the sprue cutter to one side; the cylinders are machined in a special iron alloy block with a long mounting handle, in the manner of a car's engine block (Figure 24).

The cores that are cast with a core mould do not need to be cut because core moulds are designed to be able to adjust the length of the core as it is cast. Core moulds take advantage of existing supplies of scrap lead, provided it isn't too hard

Figure 23: *Corbin's lead wire spools.*

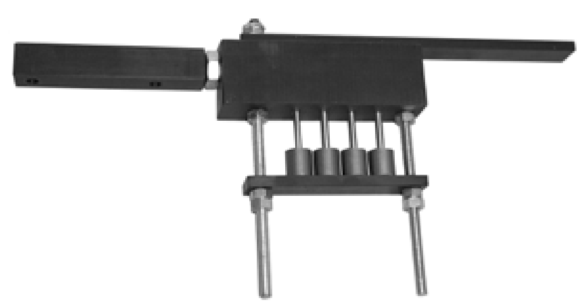


Figure 24: *Corbin's Four-Cavity Core Mould.*

for the kind of swage dies being worked with. Any hardness of lead can be swaged, but type-H dies are needed for alloys over about Bhn 10-12 hardness to avoid die breakage. Generally there is no advantage to hard lead for swaging because swaging provides many other ways to eliminate bore leading.

The CM-4a core mould comes in standard diameters of .185 in., .218 in., .247 in., .275 in., .312 in., .340 in., .365 in., .390 in., .430 in., and .489 in. Smaller diameters are not practical to cast (use lead wire or an extruder die). Larger diameters can be made to custom order. The weight is adjustable.

PRECISION CORE CUTTER (PCS-1)

Corbin core cutters mount to a bench so that the lead wire is fed straight down, into the top of the cutter. A stop screw is adjusted to stop the wire at the desired projection below the shear line of the cutter. This is what gives the desired core weight (plus a little for final adjustment in the core swage die or LSWC-1 die — usually 2 to 5 grains more than desired weight is enough to assure a good final weight control).

MAGNUM CORE CUTTER (PCS-2)

For cutting lead wire diameters larger than .365 in., the PCS-2 Magnum Core Cutter is recommended. It is nearly three times the size of the PCS-1, and uses specially made individual hardened die inserts, PCS-2D, for each range of wire sizes up to 0.5 in. This larger cutter can also handle sizes down to .185 in. but the minimum length of core is half an inch, because this is the thickness of the steel frame holding the dies.

CORE SIZE (DIAMETER)

Because there are differences in jacket walls depending on how the jacket is made or acquired, it isn't possible to absolutely specify a proper diameter for each caliber. The rule of thumb is that the lead wire or cast lead core should drop easily into the jacket, to the bottom. If it contacts the jacket wall before that point, then air can be trapped behind the core. If the core is seated, the air can be compressed to 30,000 psi, and it may be trapped in the base. (Some cores pop out of the jackets with considerable force after the seated cores and jackets have been left on the bench for a few minutes, especially if the sun happens to fall on them through a nearby window.) The right size of lead wire or cast core is that which fits easily by hand into the core swage die (CSW-1) or the LSWC-1 (for lead bullets) and yet isn't too long and thin to fit completely into the die prior to swaging. The right size of core swage is whatever makes a core that drops into the jacket all the way. The core size for jacketed bullets fits the core swage, and the output of the core swage fits the jacket.

If the jackets most often available for these calibers are used, the following table shows the core sizes, core swages, and calibers that would work, assuming normal or thinner than normal jackets (extra thick jackets require smaller cores):

Caliber	Wire Size	Swaged Core Size
.142	.100	.105
.172	.125	.130
.198	.125	.167
.204	.170	.173
.224	.185	.191
.243	.185	.191-201
.251- 257	.185	.191-220
.265- 277	.218	.220-224
.284	.218	.230-235
.308-338	.247	.249-257
.355-375	.312	.318-257
.400-412	.340	.350-370
.429-458	.365	.370-380
.475-505	.390	.400-420
.511-998	.430	.435-550

Please bear in mind that actual lead core diameters depend on the jacket wall thickness, so the next standard smaller size of wire may be needed if the jacket wall is thicker. Likewise, if lead bullets without a jacket are made, then use the lead wire size that is at least .005 in. smaller than the caliber. For instance, a .452 or a .458 lead bullet would use .430 wire, but a .429 lead bullet would need to use the .390 size instead.

CORE LUBRICATION AND CORE BONDING

When a core is swaged, it is first lubricated with Corbin Swage Lube (Figure 25) simply by applying a drop to your fingertips and rolling the core back and forth once or twice as you pick it up. No detailed ritual is required. A thin film of lube transferred to the lead surface is sufficient. If lubricating a large quantity, put half a teaspoon of Corbin Swage Lube inside a clean tumbler and load it with as many cores as your tumbler will spin without overloading it. Then turn it on and let them tumble for half an hour, or until all the cores are evenly lubricated.

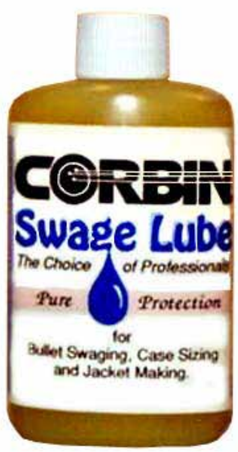


Figure 25: Corbin's Swage Lube.

The film of lube greatly reduces swaging pressure, helps ensure long die life, and eliminates lead fouling of the die and punches. Once the cores have been swaged, the lubrication must come off before putting them into jackets. Corbin Swage Lube will wash off by boiling the cores in a pot of hot water with a small amount of strong detergent added. In fact, just the hot water works reasonably well. Boiling water is useful because the heat quickly dries the cores once they are poured onto an old towel to dry. Do not let them sit around very long with moisture because they will tend to oxidize and this prevents a good core-to-jacket fit.

Swaging lubricant is not the same as bullet lubricant. Swaging lube acts as a high pressure film between the die and the bullet, reducing friction and lowering the pressure needed to form the part. It is not designed for use under high temperature; it is designed to be easily removed in solvents or water. It is clean and is normally quite safe to handle (in rare cases someone may be allergic to the castor oil or lanolin components). Corbin Swage Lube is made from medical grade compounds designed for cosmetics.

Swage Lube, however, forms a hard lacquer film when heated to annealing temperatures for copper jackets. This film prevents Corbin Core Bond from working, so be sure to wash off the lube from any bullet jacket and core that are intended to be bonded using the Corbin Core Bond process.

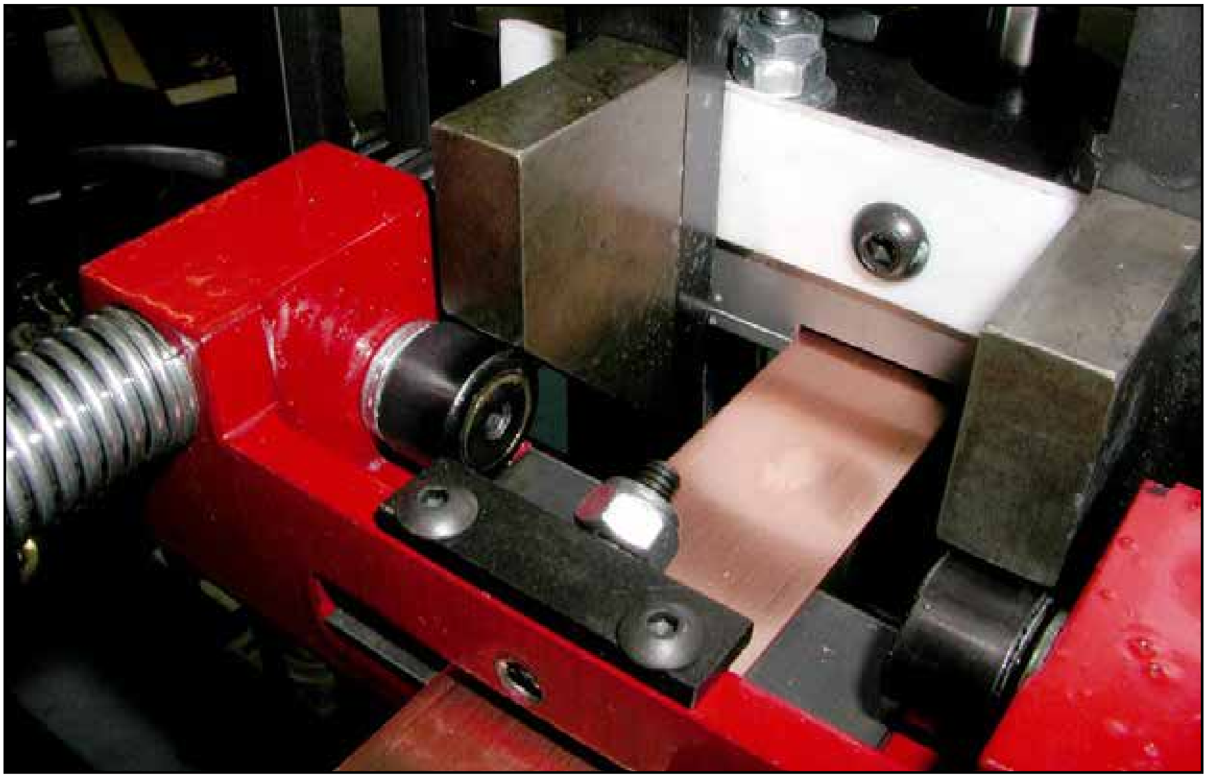
Core bonding is a process of melting the lead, within a jacket, in the presence of the liquid Core Bond (Figure 26). The Core Bond lowers the surface tension of the melted lead so that it can easily penetrate into the copper jacket, forming an actual alloy that is shallow but stronger than solder or glue by a considerable margin. The advantage of the diffusion junction between the lead and jacket is that there is

a gradient of tensile strength created, instead of a sharp junction between the 1,000 psi lead and the 18,000 to 22,000 psi jacket material.

A sharp junction, such as what exists under a layer of solder or glue, acts as a point of concentration for sudden stress. When the bullet strikes, a tremendous amount of stress is created within the bullet in a very short amount of time. The force is channeled to areas where there is a big difference in tensile strength, and tends to separate them. When the tensile strength of the materials flows through a gradient, becoming different over a distance rather than suddenly, the force of impact can flow with it and cause less concentration at that point.

The bottom line is that a bonded core bullet can usually be shot inside out and still retain nearly all of the core, whereas glued and soldered or plain unbonded bullets often separate at the junction of the core and jacket. Microphotographs taken of bonded jackets under a scanning electron microscope show atoms of lead within a one to two micron depth beyond the inner surface of the jacket wall. You don't get that with any kind of glue or other surface adherent bonding. That is the technical reason behind the fact that 90 percent of the world's custom bullet makers who build hunting bullets use Corbin's bonded core process. It is fast, low cost, and it works better than the alternatives.

Figure 26: Corbin's Core Bond.



Swaging with a Reloading Press

Some Corbin dies are designated type -R. This stands for "Reloading Press," and means that the die set was designed to fit into a regular single-station, slotted ram reloader with standard ⅞ in. x 14 threads. Any of the tools that have the -R suffix are meant for use in a reloading press. The dies screw into the press head, like a reloading press die. The external punch snaps into the slotted ram like a shell holder.

Why would dies modified for use in a reloading press want to be used, when swaging presses are so much faster and more versatile? The reason is economics: if a person already owns a reloading press and doesn't wish to make benchrest-quality bullets, but will settle for a reasonably good bullet (about equal to or slightly superior to standard factory bullets), then the -R dies may want to be used.

DISADVANTAGES OF USING A RELOADING PRESS

1. The pressure required for swaging larger calibers places a severe burden on the unhardened screw-stock rams used in most reloading presses, which can cause undue wear and distortion of the ram. Most reloading presses are not equipped with any bearings, so the pivot pins, ram, and other moving parts are placed under high frictional forces when harder alloys or larger calibers are swaged. Therefore, Corbin reloading press dies are built only for use with pure soft lead cores. If alloy lead is

used, the pressure will be considerably higher and could break the die or damage the press.

2. A reloading press has no built-in floating alignment, and in fact is generally quite sloppy compared to the alignment of an actual swaging press. This is fine for reloading because there is no real need for high precision alignment; the shell holder and fit of the cartridge case both are so sloppy that there is no gain in making the press highly aligned between head and ram. But in swaging, better bullets result from precise alignment of the press head and ram. The forces are considerably higher so that a little off-center torque can make a difference in punch life and bullet quality. The lack of high alignment precision means that certain styles, such as the rebated boat tail, are not available for the reloading press.

3. A reloading press has no built-in way to eject the bullet from the swage die. A small plastic mallet is needed to tap the plunger provided with the swage die, to knock out the bullet (and catch it with your other hand). Actual swaging presses have automatic built-in ejection when used with dies designed to fit the ram, and are considerably faster to operate.

4. A reloading press has less than half the leverage of any Corbin swaging press, since it must use about 4 in. of ram travel. Swaging only requires about 2 in. for most of the calibers and styles that can be made by hand. Therefore, by simple physics, the force is doubled with the same amount of handle travel. This makes swaging with a real swaging press far easier due to less than half the effort required.

5. A reloading press does not generally have any bearings, so they tend to wear and become quite loose under heavy loads. Corbin swaging presses such as the S-Press or the Mega-Mite travel on needle bearings with the rams guided in long oil-impregnated bushings. This extends the life and lowers the friction, which in turn reduces the effort for a given amount of thrust output.

Most loading presses have sufficiently heavy frames but rather weak, soft screw-stock rams and pins, which are sometimes reduced to half their visible diameter inside the hole, as safety links, to prevent damage to the rest of the press. Corbin swaging presses use full-diameter, hardened alloy steel links that turn inside high-pressure bearings. The swaging press can be physically smaller and yet still be considerably stronger, especially those which are built from alloy steels. The S-Press, for instance, uses 130,000 psi steel, whereas the most popular large reloading presses advertise "35,000 psi tensile strength" for their cast iron frames

RELOADING PRESSES SUITABLE FOR SWAGING

For the fired .22 Long Rifle cases drawn to make .224 or .243 bullets, almost anything can be used that will accept the dies and the punches. The little RCBS Junior press was used to demonstrate swaging at gun shows in the old days. It doesn't take a big press to swage smaller caliber bullets. A Rock Chucker's, Pacific Multi-Power's, or C-H Champion's, can be used, also. They are sturdy standard design presses. Any press with a single station head and ram, which accepts standard RCBS-type button shell holders, and has a ⅞ in. x 14 threaded top, with a physical layout similar to the Rock Chucker, should be fine.

The popular Dillon progressive reloading presses are not made for bullet swaging, and could be damaged if attempted. Most progressive or multi-station presses are best used for their intended purpose, not for swaging.

It would simplify work if the swaging presses did not need to be designed and built in addition to making the tools and die. It would also make the equipment more affordable. Unfortunately many reloading presses are not suitable for swaging.

TYPES OF DIES SUITABLE FOR A RELOADING PRESS

Gas checks can be punched and drawn from flat copper strip (.030 thickness, 1 in. wide strip is available from Corbin). The tool to accomplish this is called the Gas Check Maker, or GCM-1-R (Figure 27). It consists of two dies, a blanking die that punches out a round circle of copper, called the disc or coin, and a cupping die that turns this disk in to a short-sided cup and finishes the gas check. Corbin can make this die set for a reloading press, but it works better (less effort, more precision) in the S-Press.

Although gas checks are useful for cast bullets, the Base-Guard is even better for swaged bullets. It does everything that the gas check is supposed to do in protecting the bullet base, and in addition, helps to keep the barrel clean by actually scraping fouling out of the bore with each shot. The Base-Guard is made from the same material as a gas check, but takes only one stroke in a single die.

In a reloading press, the BGK-1-R Base-Guard Kit can be used. This is a single die and punch with a slot in the side of the die through which the inch-wide strip of copper is passed while the press is stroked up and down in a short stroke. The punch never actually leaves the die but simply drops below the slot so the copper strip can be moved. Then the punch is raised and pokes out a new disk with a hole through the exact enter. This small hole allows lead to be extruded through during the swaging process to form a rivet head holding the gas check in place but allowing it to turn with the rifling (unlike a gas check, which is clamped to the bullet so that if the bullet "skids," so does the gas check).

Actual bullet swage dies include the PRO-1-R Pro-Swage design and the -R type swage dies that make up the two, three, and four die sets for spitzer rifle bullets of the ogival type (no shoulder).

***Figure 27**: Corbin's Gas Check Maker kit.*

THE PRO-SWAGE DIE

The Pro-Swage is normally used for paper-patched bullets in rifle calibers, so Corbin will supply it with a cup base and a 1-E round nose ogive punch for rifle calibers unless otherwise specified. A popular use of the PRO-1-R (Figure 28) is for centerfire pistol and black powder rifle Base-Guard bullets. Generally, a pistol swage set would be supplied with a Keith SWC nose style and a BG base style unless otherwise specified. The Base-Guard base punch can be used without a Base-Guard disk. It simply creates a small rivet head in the exact center of the bullet base, which hurts nothing (and serves to identify the bullet among others recovered later).

A die designed to make lead bullets may also be used with gas checks. Base-Guards are much more effective at keeping the bore clean, however. Once Base-Guards have been used, it's doubtful a person would ever go back to gas checks. If the same die for gas checks, half jackets or three-quarter jackets, is used, it can be done without any change in tooling. Order and use a flat, cup, or dish base punch if the little bump on the bullet base that results from using the BG punch is not necessary.

The PRO-1-R die itself is threaded ⅞ in. x 14 so that it fits the reloading press top. The upper half of the die is screwed onto this hardened ⅞ in. x 14 body in a semi-permanent way (held with a thread locking compound). The top of the die is threaded for an adjustable bushing that can be removed to replace the internal punch, which is held captive within the die body by this bushing. A knockout rod in the top of the die pushes the internal punch down (using a plastic mallet or length of wood as a hammer) to drive out the swaged bullet. The internal punch is usually the nose (Corbin can make it the base if preferred, but it will need to be identified for future patch orders, and be sure to specify "internal" punch).

PAPER-PATCHED LEAD BULLETS

To make a paper-patched bullet (Figure 29), install the PRO-1-R Pro-swage, cut or cast some lead cores of the right weight, and swage them using the gentle, increasing-pressure method until achieving the right shape. Typically, with 0.0025 in. thick paper, the bullet should fill the grooves at .458 in. diameter with two complete wraps. Take .458 and subtract four times .0025 (two wraps, but doubled because it is on both

Figure 28: *Corbin PRO-1-R.*

Figure 29: *Rolling paper-patching on a bullet.*

sides of the bullet) and make the bullet .448 in. in diameter (before patching).

The only difference between a paper-patched bullet swage die and one for making a bullet that will be dip-lubed or grooved and lubricated, is the diameter of the swage. Most paper-patched bullets also use a cup base shape as the twisted end of the paper-patch can be tucked into it, but this is a choice. The formula for determining die size (D) for any caliber of paper-patched bullet when the barrel's diameter across the grooves (G) and the thickness of the paper (T) is known as:

$$D = G - 4T$$

If the bore size (B) and depth of rifling (R) are known, and paper thickness (T) is available, then the bullet size (and die diameter D) can be calculated this way:

$$D = B + 2R - 4T$$

Of course, shooting in a match, the rules will need to be checked first. This can be tried with paper, too, by using a slightly thinner paper than the smaller die was originally designed to use; the paper-patched bullet will fit easily into the second die and pressure will shorten and expand the bullet rather than scraping the paper off as it is inserted.

FULL JACKET, OPEN BASE (MILITARY STYLE) BULLETS

Put the bullet jacket in the point-forming die with the open end facing the die mouth. Push a piece of lead core into the jacket with a punch that fits inside the jacket mouth. The seated core should be just below the jacket mouth, perhaps ⅛ or less of an inch. Don't try to make too sharp a point because the jacket will just break through if this happens. Eject the bullet. The ogive will be formed on the normal base end of the jacket. (Having a flat-ended jacket makes no difference: the pressure will expand and reshape the end just as if the copper were a balloon skin.) To finish this bullet, the open end of the jacket must be rolled over the core.

To summarize: 1) seat the core in the jacket using the point-forming die to form a full-metal tip and open base; 2) turn the bullet over and push it backward into the point-forming die with a flat base punch to gently roll the open end into a slight boat tail shape; 3) turn the bullet over again and push it nose first into the point-forming die with a flat punch to securely flatten the jacket edge over the core. To do this more precisely, Corbin can provide a "FMJ Base-Turning" punch that has a concave face in order to help make a better fold prior to using the final flat punch. This inserts a step between 2 and 3, where the sharp fold point with the FMJ punch can be applied.

CHANGING THE NOSE AND BASE SHAPE

With semi-wadcutter and wadcutter styles, the nose shape is controlled by the punch you select. With smooth ogive bullets (those without a step between the shank and the nose), the ogive is controlled by the particular point-forming die that finishes the bullet.

Figure 30: *Ogive examples.*

Spare punches can be purchased in standard shapes of flat base, dish base, cup base, hollow base, or Base-Guard base. Nose punches can be purchased in conical, Keith (semi-wadcutter, truncated conical), 3/4-E pistol round nose, target wadcutter, button nose wadcutter, hollow point (a universal HP punch that works in conjunction with any other punch), open tip, or 1-E rifle round nose. Other custom shapes can be specified (with dimensioned sketch or sample) at extra cost for the additional shop time and tooling.

BOAT TAIL AND PARTITIONED DESIGNS

Boat tail and partitioned designs are best done in swaging presses, not in a reloading press. But a boat tail can be simulated by pushing a bullet backward into a point-forming die, thus applying a slope or angle to the base. Then form the nose in the same die by reversing the bullet. Because it takes less force to shape the open end of the jacket than to change the base shape (on most jackets the base is thicker), the same pressure will create a nose without materially removing the base angle. This doesn't work for all bullet styles and calibers, but it can be tried.

To make a good partition-style bullet, use another jacket small enough to fit inside and short enough to fill just a little more than half the larger jacket's length. Or, in the .224 and .243 calibers, use fired primers as heavy walls between two short pieces of lead core. A .243 jacket makes a good partition in a .30 caliber jacket, and a short .30 jacket fits inside a .358 or .38 jacket. A core can be seated in the smaller jacket first, with lead exposed, then the lead put end down into the larger jacket and the assembly seated like a core to expand it in the larger jacket. Top that with a short piece of lead core, and finish as usual.

OPEN TIP, LEAD TIP, AND HOLLOW POINT

For open-tipped bullets, use a punch that slips inside the jacket (and a core length short enough to allow this). For lead-tipped bullets, use a punch that fills the die bore and not the jacket I.D., or else seat the lead core very close to the end of the jacket. When the ogive is formed on the bullet, the lead will move forward and extrude from the open end if there is enough lead.

A lead-tipped bullet expands more quickly than an open-tipped bullet since the jacket is left with a larger opening. The jacket opening controls the expansion far more effectively than the amount of lead exposed. A hollow point, on the other hand, may expand faster or not, depending on what it hits and whether the initial contact plugs up the cavity and turns the bullet into an effective solid nose.

Figure 31: *Open tip and lead tip examples.*

Bullet Swaging Presses

Corbin builds several models of bullet swaging presses. The presses each have a range of capabilities and dies of a size that match those capabilities. Some older literature refers to the Silver Press (CSP-3), or the Mity Mite press (Figure 32). These are discontinued, horizontal ram cast-frame models that accepted a small diameter of die called the type -M. The -M dies used ⅝ in. x 24 threads, same as the -S dies, but had a body of ¾ in. instead of 1 in. The -M dies can be made on special order to fit older Corbin presses.

Today, Corbin builds two hand-powered presses: the Mega-Mite and the S-Press The S-Press uses type -S dies, which have the 1 in. main body with a ⅝ in. x 24 threaded shank providing a wide shoulder to adsorb axial force against the top of the ram (instead of passing the stress through the threads). The S-Press also uses a ram slotted through both sides and a long stop pin that passes completely through the ram.

The Mega-Mite uses type -H dies, same as the larger power presses. The -H dies have threads of 1-12 (1 in. diameter, 12 turns per inch) on their shank, and have a 1.50 in. diameter main body. It is suggested to use this press when wanting to make bullets larger, longer, or from harder material than can be reasonably swaged in the S-Press, or when moving toward a power press but would like to start with less investment (the dies interchange with the larger power presses).

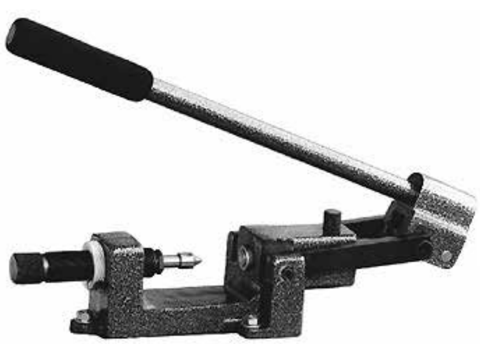


Figure 32: You may run across a Corbin Mity Mite, which is a discontinued model.

Corbin builds two models of power presses, which operate from either 115 volt 60 Hz single-phase power (standard household supply in the USA), or from 205-240 volt, 50 or 60 Hz single-phase power (optional, for export to other countries). The power presses are the Hydro-Mite (CSP-1H), which uses -S dies, and the Hydro-Press, a self-contained cabinet model with automatic timing, stroke control, and interfaces for automatic feed of copper strip for jacket making operations.

ADVANTAGES OF A SWAGING PRESS

1. Self-ejection on the back stroke. Dies that fit into the ram and have their internal punch automatically operated by a hardened stop pin so that as the handle (and ram) are drawn back, the stop pin contacts the end of the punch and stops it while the die continues back with the ram. This pushes the bullet out of the die mouth, cutting several seconds from the time required to make a bullet. Those seconds add up quickly.

2. Self-alignment of external punch and die. The external punch is held in an adjustable floating punch holder, in the press head. The punch is secured by a hex bushing, threaded with hand pressure into the holder's mouth so it pushes on the underside of the punch head, and holds it in the punch holder. A certain small amount of "float" takes place so that the punch can align perfectly with the die walls. This results in less punch and die wear, and perfectly square bases (not tipped).

3. Less than half the effort and over 300 percent more strength. Most reloading presses use a 4 in. ram travel and are cast from 35,000 psi grey iron or aluminum alloys. Corbin hand presses use half the ram travel with the same amount of handle travel, doubling the available ram thrust. The industrial chromed alloy steel ram and special components of Corbin presses result in at least 130,000 psi tensile strength. Corbin power presses are “off the charts” on both power and strength compared to any reloading press. Yet, all Corbin presses are also usable as high precision, benchrest-quality reloading presses. They can even be purchased with optional arbor press anvil inserts for use with non-threaded benchrest-type reloading dies. All come with adapters for standard ⅞ in. x 14 RCBS-type reloading press dies and button-type shell holders, at no extra cost.

4. Built for the job. Corbin swaging presses are built from the ground up for the stresses involved in high pressure swaging and will maintain accuracy while outlasting retail-trade reloading presses. Being equipped with bearings in all moving joints, hardened alloy steel rams, and other high- strength features lacking in reloading presses, the Corbin press is a lifetime investment.

S-PRESS, CSP-1

This is the most popular press today, because it not only accepts the original type -M dies, but also uses 1 in. diameter type -S die (same threaded shank size, $^{4}/_{8}$ in. x 24 tpi) in the ram. The S-Press (Figure 33) is a vertical design with the floating punch holder in the press head, which uses the same ⅞ in. x 14 thread as conventional reloading dies. An adapter converts the ram to hold regular button shell holders, and arbor press anvil inserts are available for the punch holder and the ram for use with benchrest reloading dies.

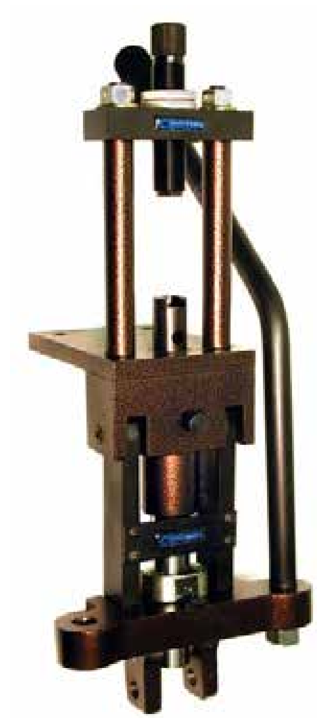


Figure 33: Corbin's S-Press, Model CSP-1.

The S-Press looks like a Roman numeral II from the front. The main components are machined from steel, not cast iron, so it is smaller and lighter than iron presses, which have less tensile strength and half the power. The ram linkage can be quickly set for 4 in. or 2 in. stroke (reloading, or swaging). A set of four needle bearings in the links provides smooth operation. Bearings also surround the ram.

Bullets from .123 to .458 caliber, with a length limit of 1.3 in., are well within the range of most small arms calibers and are also within the capability of the S-Press. The advantage of the S-Press over conventional reloading presses is the greater strength (up to 130,000 psi versus 35,000 psi); higher leverage due to the full 180°

arc of the handle; travel and dual stroke length; more sophisticated engineering (all moving contact points use bearings, including the ram, which is surrounded by 2 in. long bearings mounted in a precision honed cylinder); and capability to do reloading. The CSP-1 press comes with a FPH-1-S floating punch holder and a reloading adapter to hold standard RCBS shell holders in the ram, extend the ram height, and provide a port for spent primers to drop into the primer catcher tray, which is also provided.

The CSP-1 press would be the right choice if the plan is to make bullets from .123 to .458 diameter in lengths of 1.3 in. or less, with a core material that is no harder than Bhn 12 (and this should become less as the point becomes sharper and the diameter becomes larger, so that a spitzer .458 would probably need to be no harder than Bhn 6 to Bhn 8) in the type -S dies.

Figure 34: Corbin's Mega-Mite Model CSP-2.

If a caliber over .458 is desired, or a length of bullet over 1.3 in., or a hardness of material over Bhn 12 (such as a steady diet of wheel weight alloys or linotype) then the type -H dies and the larger presses that use them are the ones needed. No matter how much work it takes to get a die designed with less expensive equipment made for jobs it wasn't designed to do, it will most likely break.

MEGA-MITE PRESS, CSP-2 MODEL

The Mega-Mite is a huge version of the CSP-1 S-Press, weighing over 75 lb. and having a triple stroke of 2 in., 3 in., and 6 in. (Figure 34). The press also uses needle bearing links — much larger ones than the CSP-1 model — and a huge hardened steel ram guided at the top by a bearing-aligned steel plate that runs up and down on two massive hardened and ground guide rods.

The Mega-Mite uses type -H dies and can be used with the reloading adapter kit. The press head is removable, as it is in the S-Press, but uses a 1.5 in., 12 tpi threaded plate for the FPH-1-H punch holder. The ram accepts 1 in., 12 tpi threaded dies or punches rather than the ⅝ in. x 24 tpi of the S-Press (-S) dies. The standard type -H die is made with a 1.5 in.

Figure 35: Reloading adapter.

outside diameter. Custom -HC dies can be ordered with 2 in., 2.5 in., or even 3 in. diameters where appropriate for the pressure.

RELOADING ADAPTER KIT, RLA-1-H

The CSP-2 Mega-Mite press is a very capable reloading press when used with the appropriate adapter bushing and ram extender/shell holder adapter (Figure 35). It can accept .50 BMG reloading dies directly in the head (if they are 1.5 X 12 thread). The RLA-1-H Reloading Adapter kit converts the press for use with regular RCBS shell holders and ⅞ in.x 14 tpi reloading dies. It also follows that Corbin type -R dies can be used for swaging in this press or in the S-Press. With an adapter kit, some kinds of -S type dies can be used in the larger -H type presses, but it is usually not a good idea because the presses can so easily generate enough force to pop the smaller dies. If this happens often, a second press of proper size for the dies would be a better deal.

50 BMG RELOADING AND PRIMING (PT-50-H)

The Mega-Mite is ideal for .50 BMG reloaders and bullet makers. Corbin also makes a special shell holder, the SH-50-H, which is threaded to fit into the top of the reloading adapter's ram extension. The shell holder is hardened and glass bead peened, so that it will last and provide excellent grip on the big 50 case rim. One of the shell holders also comes with the PT-50-H priming tool, which is designed so you can use it in the ram of the Mega-Mite for precise adjustment of the seating depth, and also leave it in place without adjustment for depriming.

HYDRO-MITE PRESS, MODEL CSP-1H

The Corbin CSP-1H Hydro-Mite (Figure 37) is the smallest hydraulic powered press Corbin builds. It is the same general size and frame as the S-Press but is equipped with a 3/4 HP 120 volt AC remote-controlled power system. The smooth, quiet operation makes the normally long jobs of jacket drawing, bullet reducing, or case sizing go quickly with almost no physical effort. The press isn't as well suited for bullet swaging as the other hydraulic or hand presses,

Figure 36: *50 BMG priming tool (PT-50-H).*

Figure 37: Corbin's Hydro-Mite Press, Model CSP-1H.

however. It is very highly recommended for making jackets and other redrawing operations, but not so highly for bullet swaging.

Although the press can generate more force than hand presses, the main advantages are the lack of effort required (even disabled persons can perform long runs of production without becoming tired) and full power from start to finish of the stroke. It is a linear power stroke rather than the log power stroke of a hand press, meaning that drawing operations, lead extrusion, and other jobs that use the same power at the start as they do at the end can be accomplished.

The press has the same caliber and length limitations as the hand-operated CSP-1 because the same dies (-S) are used. But jobs that normally require adjusting the punch holder back and forth to get enough force at the end of the hand-operated stroke can be done in one pass without moving the adjustments. For this reason, the CSP-1H Hydro-Mite can produce more jackets per hour (and the operator does not tire nearly as soon).

The Hydro-Mite is ideally suited to production runs of small parts, such as drawing .22 cases into jackets. Because sufficient power can be generated to easily pop a type -M die of nearly any caliber, it is not recommended to use anything except type -S dies in the Hydro-Mite press. This is not to say -M dies would break or-S dies couldn't break. Any die can be broken with enough applied pressure, and pressure can be focused on a narrow point in any die by using hard materials, which do not spread out and distribute the force until high levels of localized pressure are reached.

HYDRO-PRESS, MODEL CHP-1

The CHP-1 Hydro-press (Figure 38) is used by more custom bullet firms than any other press. It forms the basis for successful bullet making businesses around the world, from Australia to South Africa, Nova Scotia to Paraguay. This press can be ordered with either 120 volt, 60 Hz power (1.5 HP), or with the choice of domestic 60 Hz 220 volt or export 50 Hz 240 volt power (1.5 HP). It weighs about 350 lb., and is self-contained within a sturdy steel cabinet having a colorful Lexan-overlay work surface, with color-coded indicator lights and controls.

The CHP-1 has an adjustable stroke from 0 in. to 6 in., making it capable of loading the largest cartridges and forming bullets with calibers as large as 1 in. diameter. There is no limit to the jacket wall thickness, other than practical considerations of performance. Virtually solid jacket material can be swaged with merely a tiny hole through the center, or in some cases, even copper rod with an axial hole part way through the ogive end, if requested; the dies can be designed to handle the pressure.

Figure 38: Hydro-Press, Model CHP-1.

The normal die size is 1½ in. in diameter, but custom dies can be made as large as 3 in. Custom dies of 2½ in. diameter are sometimes built to handle slightly higher than normal pressures. Such dies are quoted individually depending on features needed.

The ram is threaded for 1 in. x 12 threads per inch (tpi), and moves inside precision fitted guide bearings. The press head is aligned and guided by a heavy steel plate, which itself runs up and down on two high-tech frictionless bearings on hardened and ground steel guide rods.

NOTES

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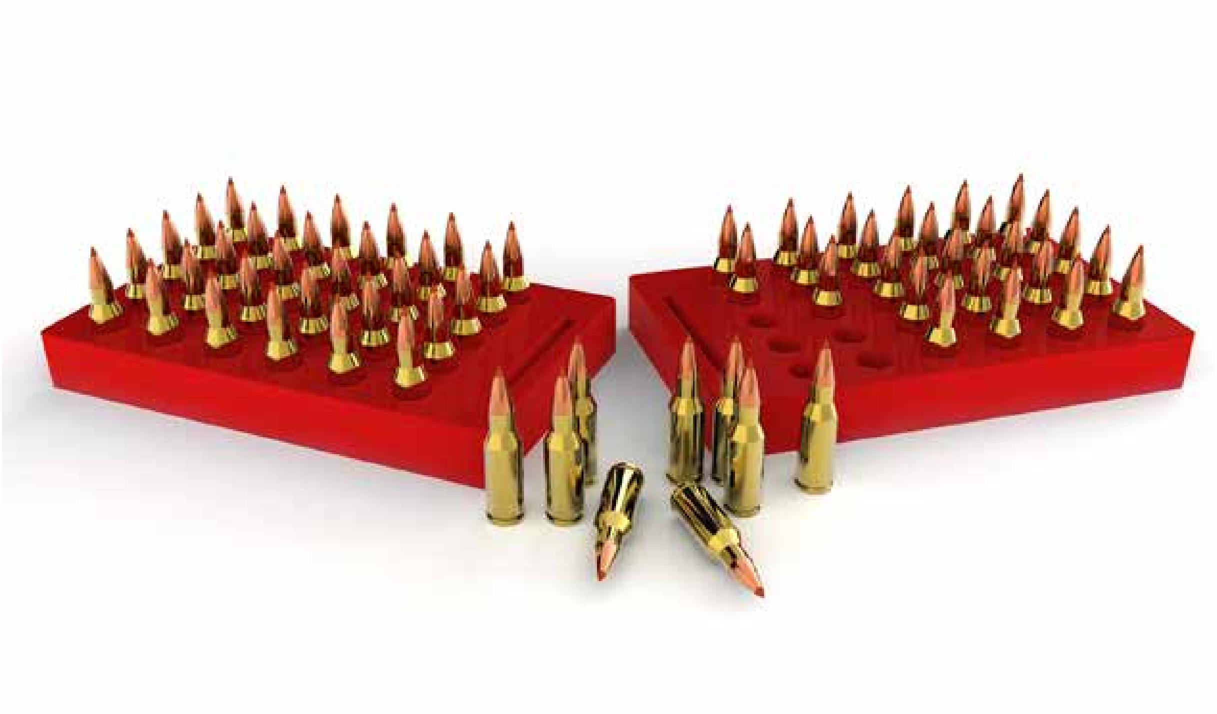

Lead, Base-Guard™, Gas-Checked and Paper-Patched Bullets

Bullets that have a shoulder between the nose section and the shank can be made in a straight cylinder kind of die by using a punch that has the nose shape machined into a cavity. The edge of the punch cannot be knife-edge thin because it would soon break off from the stress of being pressed under tons of force against the die wall and then moved to eject the bullet. In fact, the edge would break off at a ragged point about .020 in. thick.

A straight hole through the die cylinder fitted with a close-fitting punch that has the nose shape machined in reverse (a cavity) can form lead, gas check, Base-Guard, or paper-patched bullets with virtually any shape of nose. Items that can be made include wadcutters, semi-wadcutters, big hollow cavities like the old Webley Man-Stopper, sawtooth bullets, and even pointed rifle-type bullets — provided the nose is all lead and the jacket stops where the punch begins, with a shoulder the width of the punch edge.

MAKING HOLLOW POINTS

Hollow point noses (Figure 1) in the lead SWC bullet can be made in two ways. First, use a separate HP-type external punch to poke a hole in the nose, which of course displaces lead and changes the nose shape.

The second way to make a HP cavity is to get a custom punch with the HP probe and nose cavity combined in one punch. This kind of punch can have an adjustable HP depth if the probe is straight (rather than tapered), so its position can be adjusted by changing a screw depth in the punch head. The end of the punch can be tapered, but if adjusting this part back into the punch body, lead will flow up around the taper and make a nipple on the end of the bullet.

GAS CHECKS AND HALF JACKETS

For gas checks and half jackets, the lead slug that is used for the core must fit inside the jacket or gas check before it is swaged to final size. The jacket should always be slightly smaller than the final bullet diameter so it will fit easily and expand upward, creating a snug fit on the lead when you release the pressure. If the jackets are, for instance, 0.3575 in. diameter and the die has a bore of 0.3570 in. diameter, all that happens is difficulty forming and loose cores or gas checks that pull off from base drag on their way to the target.

***Figure 1**: Hollow point bullet.*

BASE-GUARDS

Base-Guards are conical disks with a hole in the middle, like a very wide washer. The hole is usually about ⅛ in. in diameter. The Base-Guard is normally made of copper, about .030 in. thick. Because they are conical, they will expand when compressed and become the exact size of your swage die. Any surplus metal will be extruded forward to form a burnishing tool edge because one side is backed by the steel punch and the other side only faces soft lead. This scraper edge will engage the rifling and push fouling out ahead of it, making it unnecessary to use any bullet lubricant, up to reasonable velocities of 1,200 to 1,400 fps.

Figure 2: *Various nose shapes.*

The best way to make a Base-Guard bullet is to first swage the lead slug into the bullet shape using either a flat base punch or the special BG punch, which has a shallow depression in the exact center. Then eject the bullet, drop a Base-Guard disk into the die with the cone tip facing out, toward the bullet, and swage the bullet again.

PAPER-PATCHED BULLETS

For paper-patched rifle or handgun bullets, nothing special is required except possibly using a cup base (CB) internal punch instead of the usual flat base punch. There are actually three standard base cavity shapes that Corbin produces (as well as any custom dimension you wish, of course). These are dish base (DB), cup base (CB), and hollow base (HB).

The dish base is a shallow curve that extends from one side of the bullet to the other, with no flat "margin" on either side. It is used to slightly force the edges of the bullet against the rifling so that moderate loads of slower burning powder will quickly expand the bullet into the bore and prevent early gas leakage. It is used when the pressure is fairly high (hot loads) and cup or hollow bases might become flared excessively from the muzzle gas pressure.

The cup base is a deeper curve with margins on the sides, designed to hold moderate muzzle pressures in black powder rifles and in modern target handguns firing typical target loads. The curve is less than one caliber in depth (typically 0.02 in.). It is very useful in paper-patched bullets as a place to tuck the extra paper gathered at the bullet base, and can help fit a standard diameter bullet to various bores during firing.

The hollow base (HB) is the deepest curve, with margins that are designed to hold muzzle pressure so the base won't expand excessively when the bullet pops out of the barrel. The design is to shift weight forward and lighten the bullet for its length. Airgun pellets, shotgun slugs, and muzzle loader bullets that are made to slide down the bore and then expand into the rifling on firing generally work best with this design. It is not usually employed for paper-patched

Figure 3: *Example of die for making paper-patched bullets.*

bullets, but there is no particular reason why it cannot be done. Just order the internal LSWC-1 punch with "HB" designation. (Usually, the top or external punch is the nose, and the base is inside the die or internal.)

Of course, the big difference between a paper-patched bullet and a lead bullet is the diameter of the die. With a paper-patched bullet, the die should be smaller than the groove-to-groove depth of the bore by four times the thickness of the paper. To illustrate with making a .45-70 paper-patched bullet: if the bullet were to be a Base-Guard, gas-checked, or have lube groove or knurling rolled into it with a Corbin HCT-3 grooving tool or HCT-2 knurling tool, then the die should be .458 diameter (Figure 3).

HARD LEAD ALLOYS

In the Hydro-Press, moderately hard lead can be swaged in a LSWC-1- H die (Figure 4) that is designed for the job. Be careful to use the orange press-fit guards around the die, however. The pressure that it takes to extrude the lead is very high, thousands of pounds, and can build up before the lead extrusions finally move through the bleed holes. When they do let go, they can fly out at fairly high velocity. They are generally light and not very aerodynamic, so they lose velocity quickly and are easily stopped. Stopping them with your body could be painful when using hard lead because of the higher pressure; the guards work much better.

How hard is too hard for a standard die? That depends on the caliber and the bullet shape, to a large extent. If the die cavity is very long and narrow, as with sharply pointed spitzer bullets, the pressure required to force hard material into the nose will go up quickly. The same material might form a round nosed bullet in the same caliber with relative ease. Soft lead is 5 on the Brinell hardness number (Bhn) scale. Each integer increase is a square function of hardness, so going from Bhn 5 to Bhn 10 is not twice as hard, but more like four times as hard. Experience has been that the pressure is related to the increase in hardness with most materials, including gold, silver, lead, aluminum, brass, copper and other commonly swaged materials.

Figure 4: *Example of LSWC-1- H die.*

If a die has a breaking strength of 150,000 psi, and pure lead flows in a given shape completely at about 20,000 psi, then you can see that raising the pressure four times probably will work but going up eight times would blow up the die. Therefore, if the hardness is increased to Bhn 20, the die would probably crack before the metal formed into proper shape. There is no hard and fast rule about hardness. The die wall thickness helps increase strength, of course, but eventually the tensile strength of the die material is reached, and then the thickness hardly matters. Any die can be broken with enough pressure. The pressure required to form even moderately hard lead can be too much for the smaller -R dies, so they are warrantied only for use with soft lead.

The larger -S dies generally work with up to Bhn 8 to Bhn 10 hardness, but even this depends on the shape and the operator. If the handle is jerked quickly, it can blow up nearly any die from the combined shock and pressure. A positive, smooth application of pressure only builds pressure from the straight math involved in the force divided by the cross-sectional area to which it is applied. But a rapid jerk of the press handle adds both inertial resistance to flow and kinetic energy from the velocity times the mass of the moving parts. The sum or end result of this, plus the static pressure, is what is referred to as "shock." It is similar to what happens when the trigger is pulled with a load of fast-burning powder and a heavy bullet. The pressure soars to a high peak and then drops off to a lower level as the bullet starts to move. This sudden pressure peak can far exceed the breaking point of the die, and is also one of the few reasons why anyone would break a hardened link pin.

JACKETS THAT COVER THE BLEED HOLES

A note about jackets that cover the bleed holes in the die: if wanting to use a ¾-length or full jacket, the -H dies can be tried. Chances are it will work, unless the jacket is too thick or hard. Lead will simply blow a hole right through the jacket wall and there will be three tiny, shiny dots of lead showing through that lock the core into the jacket. If this is tried with the -M or -S dies, there is a risk of die breakage, or, at best, hard ejection as the jacket bulges into the bleed holes but does not let the lead pop through. In large calibers such as .40 to .45, the die walls are thin enough that it will probably break the die if kept up for very long, and die breakage from overpressure is not a warranty problem. (If a die does break, send back the punches and Corbin can make just the die body, thus saving you a fair amount of the total die cost.)

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Jacketed Semi-Wadcutters

If needing to make a jacketed bullet, and the jacket must cover most of the bullet's shank, then the LSWC-1-style of die won't work because it has bleed holes to adjust the bullet weight right in the side of the die. The long jacket would block them. Instead, graduate to the next level of equipment, where a lead core is swaged in one die, at a diameter that will fit into the jacket for the caliber, and then seat the core into the jacket in another die that makes the bullet full diameter.

These two dies are called the "Core Swage" and the "Core Seat" dies. The Core Swage (CSW-1) must be large enough to accept the lead core wire or cast core by hand, and not so large that it produces a finished core too big to fit all the way to the bottom of the jacket wished to be used. Different jackets may have different wall thicknesses and internal tapers, so changing the jacket might require a different size of core swage die.

MAKING BULLETS IN SETS THAT USE THE CSW-1 CORE SWAGE DIE

Cut or cast a piece of lead to approximately the right weight, plus a few grains. Put an empty jacket in the scale pan and set the scale weights for the final bullet weight wanted plus about 3 to 5 grains extra. Snip off a length of lead about equal to the jacket length or longer if planning to make a semi-wadcutter. This can be done by trial and error the first time (measure a bullet length of the desired weight, as a starting point). Once

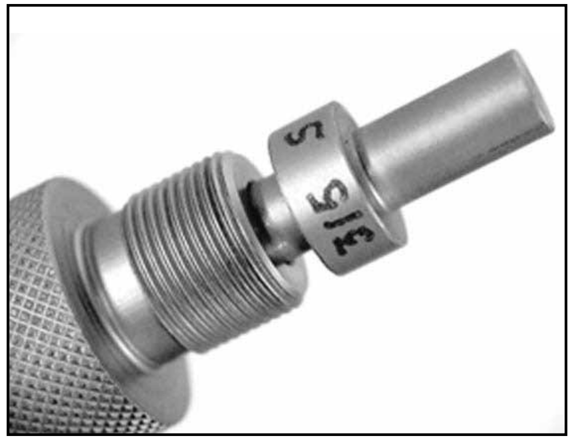

Figure 5: Core swage die.

the desired weight is achieved, save one core as a gauge and use it to set the tools next time.

Lubricate the cores lightly with Corbin Swage Lube. Roll them on a lube pad, handle them with a little lube on the fingers, or roll them in a tumbler with some lube added. The lube is to keep the dies in good shape and reduce the amount of force and wear. It is removed before putting the cores into jackets or shooting the bullets. Swaging lube is not the same as bullet lube: it isn't for reducing fouling in the bore but only for reducing pressure and friction in the dies.

Put the CSW-1 die and its internal punch in the press ram and put the external punch in the press head (in the FPH-1 floating punch holder). A retainer hex-bushing holds the punch in the long, threaded punch holder. (The FPH-1 punch holder looks like a reloading die and is sometimes confused with a die by beginning bullet makers.)

Put the lubricated core into the die and run the ram up so that the external punch slips into the die mouth. Make sure that the core is completely inside the die before any pressure is needed, and that the core is small enough to drop easily into

the die. Also make sure the external punch is the correct one: it must fit easily into the die by hand, but be a close enough fit so that if it were not for the bleed holes a vacuum could be pulled inside the die with the punch. Swage one core, weigh it, and adjust the punch holder position so that the desired core weight is achieved. The core weight plus the jacket weight should be exactly what is wanted for the final bullet weight. Also, bleed off from 3 to 5 grains minimum — a little more does not hurt anything. Do not try to extrude it too fast, though. A gentle firm push that takes a full second or two is about right. Rapid extrusion can build pressure and generate excessive "shock," which is just another term for transient high-pressure surges. Enough of that can crack a die that would normally handle the load applied at a slower rate.

For the maximum benchrest precision in core weight, double swage the cores. Swage them all once, and then put them back into the die without changing the setting and swage them all again. If using a hand press, try holding the pressure at the top of the stroke for just a second or two. If using a Hydro-press, set the dwell time for a second or so, and make sure that the pressure is high enough to extrude immediately, with no apparent delay. For the ultimate in precision, use the FPH-2-H Positive Stop Punch Holder. It eliminates any drift in ram position, and enforces an absolute stopping point by actually stalling the ram, using the pressure-reverse feature of the Hydro-press to automate the procedure.

Make as many cores as you need, then remove the CSW-1 core swage die and install the CS-1 core seating die and punches. For ¾-jacket handgun bullets, use an external punch that fits into the die closely, with a cavity in the end of the punch shaped like the bullet nose you desire to form. The normal handgun set comes with either a ¾-E round nose or a Keith SWC nose punch. Other shapes, standard or custom, can be specified.

SEATING THE CORE

Seating the lead core into the jacket is a bit of an art: learn how much pressure expands the jacket to the size of the die and how much more would be hard on the tooling. Normally, once the jacket expands to the diameter of the die, it is complete. Higher force only stresses the die and does not give a better bullet.

Corbin prefers to gently seat the core and see if the core and jacket stay in the die or if they come back out on the punch. If they stay in the die, odds are good the jacket expands enough to make it press against the die walls. If lead bleeding gets past the punch with light pressure, it just means that the core seating punch is too small. Enough pressure cannot develop to expand the jacket to correct diameter with an undersized core seating or nose forming punch.

Make a lighter bullet in a longer jacket by using either a plastic "bullet ball" to take up some of the space in the bottom of the jacket, or filling the bottom part of the jacket with compressed cornstarch. Cornstarch can easily be

Figure 6: Core seat die.

compressed into the bottom of a small cardboard pill box, using the lid of a telescoping box to hold the powder and the bottom as a piston to compress it.

This firm layer of cornstarch will take up about a quarter of the original height. Then, use the jackets like cookie cutters, pushing them down into the firm layer to insert a specific amount of material into the jacket. One, two or three "cookies" can be pushed into the jacket, as needed to take up room without adding much weight. Then the lead can be seated on top. The bullet will have the length of a heavier projectile.

A heavier bullet in the same jacket can also be made just by making a longer nose, less of a hollow base (switch to cup or dish base to make the bullet heavier in the same length), or by letting some of the lead core extend past the jacket at full diameter. This is not necessarily the best design, because lead touching the bore will cause fouling at some velocity, eventually. Two jackets can be telescoped end to end over a single core, squeezed in the core seating die with a wadcutter nose punch, and made a fully jacketed bullet that is longer than any available single jacket.

With any semi-wadcutter design of bullet (which also covers wadcutters), it is very important that there be at least a tiny amount of lead extending past the end of the jacket. The reason is that there is no way for the jacket edge to jump over the punch edge. If expecting the punch to last, it has to be made with a minimum of .020 in. of thickness at the edge. Otherwise, the force of moving the punch after applying tons of swaging pressure to the bullet would simply expand the thin edge against the inside of the die and rip it off. There would be about .020 in. of edge thickness, but it would be rough and broken. Better to machine it neatly where it would normally break anyway.

This edge means the jacket curve cannot be made away from full bore diameter in the LSWC-1 or CS-1 die (both of which use the punch cavity to form the entire bullet nose). Hence, both kinds of straight wall dies, using a punch cavity to form the nose, are restricted by physics to making lead-nosed bullets with a shoulder. Below the shoulder, it doesn't matter if there is a jacket or not because either lead or a jacket will expand nicely against the die walls.

If trying to make a bullet that has too light a core for the jacket length, the nose punch will compress the lead until the punch edge contacts the jacket edge, then proceed to crush the jacket. Making the lead core heavier solves this problem. If wanting to make the same weight of bullet, use a hollow base, cup base, hollow point or a light filler in the jacket. Any of these methods will displace some lead, cut down the weight (or keep it the same) and move the core forward so it has room to fill the entire cavity in the nose forming punch.

If the bullets have an angle or uneven spot on the nose, it probably means that the core isn't

Figure 7: Wadcutter designs.

long enough to fill the entire nose cavity in the punch, or the lead is too hard to flow at the pressure that can safely be applied with that die, or there is trapped lubricant between the punch cavity and the end of the bullet. Normally, this problem won't happen with the JSWC-2 die set because swaging the core in the first die makes the end square and smooth so it flows evenly into the nose punch in the next operation.

But, if these symptoms do occur, use pure lead just to see if the supposedly soft lead is really not so soft after all. Hard lead is much more difficult to flow than pure lead. Alloys that seem soft to you might actually be fairly hard compared to pure lead. A rule of thumb is that each 2 point increase in Bhn will just about double the pressure required to fill out the bullet completely. Soft lead is Bhn 5 and Linotype is about Bhn 22. Most wheel-weight metal ranges about Bhn 10-15. Going from Bhn 5 to Bhn 7 may double the pressure needed to make the edges form completely. This is fine if the dies will handle the pressure. The type -M dies can only handle pressure designed for Bhn 5 to Bhn 6 hardness of lead, especially in the .40 to .45 caliber sizes. Type-S dies may handle up to Bhn 10-12 alloys, and type -H generally handles any lead that can be put into them (but that does not mean the dies will never break, no matter what happens: they can be broken from applying too much pressure or applying it too fast, just like any other die).

CHANGING NOSE AND BASE SHAPES

More than one nose punch can be used on the same bullet to achieve special effects such as various diameters and depths of hollow points. Thousands of shapes that are not exactly the same as either of the punches can be created by remembering one thing: once the force needed to expand the jacket fully has been applied, it doesn't have to apply that level again. This means the next punch can be pushed into the die as lightly or as short of full contact, and only partially make the bullet nose reform to the new shape.

The most versatile way to make a hollow point, for instance, is to use two punches. First, form a giant hollow cavity by seating the core only with the HP punch, which has a conical projection on its tip. What has just been made is something similar to the famous old Webley "Man-Stopper" excellent short-range defense bullet for revolvers, which might not feed in some autoloaders.

Now, pick out a second punch, be it round nose, or Keith, or any other shape of cavity (wadcutters are not as effective). Push this punch only partly into the die, lower the ram, and examine the bullet. Adjust the punch holder so that the punch consistently forms the desired shape at the very end of the ram travel so you don't have to guess how far to raise the ram — just go all the way up, with the punch holder set high enough to prevent full pressure and complete reforming.

Figure 8: *Saber punch.*

Play with the punch holder position, using the end of the stroke each time, and see how many interesting different bullets can be made with only two punches. Change back to the hollow point punch and see how reversing the order of use makes a completely different shape bullet, even if both punches are used to the same relative depth of insertion. Try using a flat or wadcutter punch to push the base into the die with a cup base or hollow base punch (internal), forming the nose against the internal punch, then reversing the bullet direction for a second pass with the punch holder set higher.

One favorite is the large HP punch followed by a Saber punch (as in the saber-toothed tiger). This punch has a number of saw-teeth cut into the steel of a concave curved surface (Figure 8). This becomes a sort of buzz-saw bullet that zips through targets. It is a crowd-pleaser, assuming the crowd is not made up of attacking wolves or feral pigs. Put a few of those on the table at a gun show and see how fast they are picked up by handloaders.

Six teeth is the optimum number for this kind of punch because eight makes the teeth too thin and they won't stand up very long to the high end pressure. The edge of the jacket can be nicked on purpose with these teeth to help it start expanding, but don't try to actually cut down into the jacket material very far. This will soon overstress the sharp edges and break them. As long as most of the Saber teeth are formed from the lead extending beyond the jacket, this concept works very well.

MINIMUM AND MAXIMUM WEIGHT LIMITS

Core seating and core swage dies have a maximum and minimum weight limit, related to the length of the core and jacket. The heaviest possible weight is reached when the core and jacket are so long they do not allow for the external punch to be put through at least a full caliber length into the die. At least one caliber length is needed along the external punch to be supported and guided by the die cavity before any pressure is encountered. Otherwise, the punch may be driven off to one side so that it is damaged by striking the die mouth, or pressure in a nose forming cavity or rebated boat tail cavity may build up to the bursting point of the thin punch walls since they are supposed to be supported by the solid steel die walls when pressure is applied.

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Full Jacket, Flat Base Bullets

The previous chapter described a 2-die set called the JSWC-2 using a CSW-1 Core Swage and a CS-1 Core Seater. This set could make jacketed or lead bullets, but the bullets could not have the jacket curved inward away from the shank because a step was required between the nose and the shank. The edge of the jacket would strike the edge of the nose punch and be crushed if too light a bullet was tried to be made or the jacket forced into the nose punch. By adding one more die, the shoulder can be eliminated.

If the PF-1 "Point Former" is added to the JSWC-2 set, it now becomes the "FJFB-3" set. This is referred to as a "Full Jacket Flat Base" set because that is the main or basic bullet design that it makes. Using various techniques, this set builds both rifle and pistol bullets. It can make open base military-type full jacket or closed base open tip full jacket bullets. In the closed base full jacket style, it can produce both open tip and soft point bullets, with some limitations on the sharpness of the soft-point (which are overcome by adding a fourth die).

Everything that applied to the JSWC-2 set still applies here, except that the ogive or nose can be built on the jacket, if preferred. The PF-1 point-forming die has a cavity shaped just like the bullet wanting to be made, instead of forming the nose in a punch cavity. This eliminates the edge of the punch and thus eliminates the need for a shoulder on the bullet.

In bullet swaging, "open tip" and "hollow point" are referred to as two completely separate features. The open tip (OT) is made by pushing a lead core into a jacket so that the core is shorter than the jacket by enough to allow the point to form and leave the core short of the bullet tip. The core just stops and the jacket continues, leaving an open space inside the tip. This can be filled with a plastic "bullet ball" or left open. This is the open tip. It is made with an open tip core seating punch, supplied as a standard item with rifle caliber 3-die sets. This punch fits the inside diameter of a particular jacket, at a certain distance from the mouth, and seals the pressure at that point to allow the core to be seated.

The hollow point (HP) is made by pushing a conical-shaped projection machined on the core

Figure 9: "Full Jacket Flat Base" set.

seating punch down into the lead core. This can be done regardless of the length of core compared to the jacket. If the HP punch fits down inside the jacket, then make an open tip bullet that is also a hollow point. That is referred to as OT-HP in the Corbin terminology, which means Open Tip Hollow point.

Technically speaking, the lead can be seated so it comes to exactly the same length as the jacket after the ogive is formed. But this is just a little bit too fine an argument to create a new name because in order to accomplish this, the core will be seated below the jacket in the open tip style prior to forming the ogive. The lead always moves forward to some extent, and this is just a matter of setting the open tip style so that the lead moves right the jacket edge when you process it through the PF-1 die. It can be called a "flush tip." Nosler calls that design a "Protected Point" since the lead is more or less protected by the jacket.

FULL METAL JACKET BULLETS

Full metal jacket (military style) bullets can also be made by turning the jacket backward so the base faces the cavity of the PF-1 die, and actually seating the lead core into the jacket in the PF-1 instead of in the CS-1 core seater. The pressure changes the flat jacket end into a pointed shape, conforming to the die outline. But the base is still wide open (the lead core should come just about 1/8" below the jacket mouth).

To make a proper base, eject the bullet, turn it over and push it back into the point-forming die. But use a special "base-turning" punch that has a shallow concave face. This punch doesn't do anything a flat punch wouldn't do at this point, but it will in the next step and it saves from changing punches yet again. Just barely push the open end of the jacket into the ogive portion of the PF-1 die so it acquires just the start of a curve. Then eject the bullet and turn it over one more time. Press more firmly this time, using the "base-turning" punch. Because the jacket edge has already been curved inward, it will contact the face of this concave punch closer to the center than the very edge, and will be curled inward and nearly flattened.

REMOVING A STUCK BULLET

If a bullet should stick in the point-forming die, don't panic. The first thing to do is to stop, take the die out of the press, and gently turn and pull the ejection punch out of the die. If it is stuck too hard to pull out, it may have to be driven out by pushing on the wire tip, but twist and pull carefully and free it from the stuck bullet. The next thing to do if wanting to ruin the die and buy another one, is to get out a drill or tap extractor or a torch and drill, tap, or melt the bullet out. This is the best way to insure a good retirement income for the die-makers, because it normally ruins the die surface or temper of the carefully heat-treated die. It seems to be the first thing inexperienced bullet-makers do, other than panic and break the ejection punch by continued attempts to eject the bullet.

The right way to get the bullet out is to push it in farther. Leave the ejection punch on the bench and put the die back into the ram without any internal punch. Use the normal external (top) punch to push the bullet down just a tiny bit farther, which closes the hole in the bullet, pushes the jacket edges at the tip closer together, and gives the ejection pin (if it were present) something to push against. Then, unscrew the die from the press and use a short piece (about an inch long) of the same diameter wire as the ejection punch to drive the bullet out of the die.

Of course, the die and punches can be sent to Corbin to remove the bullet at no charge, other than the return shipping and insurance cost. Sometimes, Corbin will drill a hole in the bullet and screw a self-tapping screw into the hole and

then use a pry to pull the screw and bullet out. It may be possible to do this without harming the die, but if the drill or screw is forced against the highly polished die wall and causes a mar in the finish, it is not a warranty problem (unless done by Corbin). It is suggested to try the push and short pin method first. It has very little risk and almost always works in two to five cycles.

If an empty jacket is pushed into the point-forming die, or if the bottom should break out of a jacket, then there may be no core left to push against. It may be possible to insert another seated core and jacket with plenty of lube on it and use this to collapse the empty jacket into a ball, which in turn provides material under the ejection pin tip for ejection.

Figure 10: Bullet stuck in die.

Lead Tip Bullets

The LT-1 lead tip forming die is available in type -R, -S, or -H sizes. It is similar to a CS-1 core seating die in that the die has a straight hole all the way through, and punches that are full bore size of the die. However, the diameter is just slightly larger than the finished bullet, whereas the core seater is slightly smaller. The internal punch has a cavity machined in the end, shaped similar to the ogive curve of the bullet to be formed, but with a slightly wider angle.

To make a large round or flat-tipped lead nose bullet (Figure 11), this die may not be needed. Just seat the lead core so that it projects beyond the jacket being used, form the nose in the point-forming die, and then it is done. If the point-forming die is designed especially for lead tip bullets, it will have been made with a larger than usual ejection punch. This spreads out the force of ejection over a wider area, and reduces the visibility of the mark that the punch makes

Figure 11: Lead-tipped hollow point.

in the bullet nose. Normally, it is acceptable if even a little circle can be seen where the ejection pin pushed against the lead nose.

Lead tip bullets require that the jacket be left open sufficiently so that the tip is connected to the main core by a substantial stem of core material. If trying to close the jacket down to a tiny tip in order to make a very small lead tip, push the two jacket walls so close together that nothing is left to hold the tip to the core. It can actually fall off the bullet when trying to load it into the cartridge case, or even when the gun cycles and pushes the cartridge out of the magazine.

The LT-1 die helps do one other operation: it not only shapes exposed lead tips into factory-finished appearance, but it also sizes the base portion of the bullet to minimize the "pressure ring" at the base. This is a very subtle amount of sizing, not the same as removing body taper from a mass production operation by shoving bullets through a ring die (which tends to loosen the cores). It is useful in hunting rifles and autoloading handguns because it helps keep the case neck snug and parallel to the bullet.

CHANGING OGIVE SHAPES

The LT-1 die itself is made in a specific caliber (diameter) but the ogive or nose shape can be changed by getting a different internal punch. The internal punch in the LT-1 die has a cavity that matches whatever lead tip shape is desired. If wanting a semi-spitzer shape, this means the ogive is a spitzer but the lead tip ends with a very perceptible radius. If wanting a spitzer tip, then the lead tip cavity will end with a small radius. Generally, it best to make spitzer lead tips with a small radius. This helps the lead fill out to the same consistent length. Lubricant build-up can sometimes block a very sharp cavity so that some tips come out needle-sharp and others come out with a poorly formed end, either angled or flattened. Unless given other instructions and drawings with dimensions, the spitzer lead tip punch ends with a tiny radius.

To order a different lead tip shape, specify the ogive of the point-forming die being used to make the bullet and then request a flat tip, semi-spitzer, spitzer shape, or some special shape. If wanting a flat tip or special shape, a drawing with the dimensions will be needed, or a few samples. One sample is fine except that it doesn't provide an idea of the tolerance range. In the absence of any other instruction, Corbin's standard practice will be used as a guide.

To change shapes, change the internal punch. Some people have suggested using a larger LT-1 die for smaller bullets, such as forming a .284 lead tip using a .308 die. It isn't a good practice because the bullet can be randomly expanded and the tip may not be perfectly centered with the axis of the bullet.

TIP CLOSERS

A tip closing die is a lead tip die equipped with a special hardened punch made of a tough, wear-resistant steel alloy. The cavity in the punch is made so that the tip of the open jacket will contact it first, and the force will move the jacket tip inward. Sometimes the jacket will be strong enough to allow the tip to be almost completely closed in this manner. Usually, the jacket only allows a reduction in the open tip size, not complete closure, because the jacket will collapse, fold, or take on the edge shape of punch and thus create a shoulder on the ogive.

ULD METAL TIPS

The ULD or "Ultra Low Drag" bullet design (Figure 12) was first made by Corbin back in the days of the Vietnam conflict for long-range sniper rounds. It combined a rebated boat tail with a relatively heavy bullet having a secant ogive with a 14 caliber radius offset 0.014 in. from tangent. For any given weight and caliber, this shape provided the best compromise between ballistic coefficient and accuracy within practical recoil and pressure levels.

Fast forward a few decades, and the ULD design has been copied under a half-dozen other names, but all retain most of the features found in the original design (except for the rebated boat tail, since so much equipment, advertising, and customer conditioning have been put into the conventional boat tail by this time, and the conventional boat tail base is easier to load in automatic equipment than a flat or RBT base). But two new features have been developed, tested, and are now available to handloaders and bullet makers.

The first additional feature is a blending of the secant and tangent ogives in a "hybrid" design, which reduces the slight chance that a secondary shock wave might be momentarily generated at the ogive-shank junction under exactly the right combination of velocity and air density. This improves the BC by a very small amount for a given weight and diameter of bullet. (Remember, BC is reduced by the square of the diameter, and increased directly with weight, so you can always get higher BC by making the same design and caliber of bullet heavier or using the same shape and weight in a smaller caliber — if the internal ballistics and the firearm mechanics safely permit it. Keep in mind also that BC and accuracy will always go in different directions at some point, if the BC is increased beyond certain limits by making the bullet longer and heavier.) When ordering a standard "ULD" point-forming die from Corbin today, the hybrid-style ogive is provided rather than a conventional secant, although it may be hard to tell much difference by eye. The main difference is the blending of the angle or junction between shank and ogive.

The second additional feature, which is optional and requires some special equipment (different kind of point-forming die, extra punches), is the "ULD TIP" design, using a CNC-machined high precision, metal tip insert having a needle point. The conventional ULD point-forming die cannot seat this tip properly. A special

Figure 12: "Ultra Low Drag" bullet design.

Figure 13: ULD tip insert.

PF-1-ST or PF-1-HT tip-seating and ogive-forming, with two different ejector punches used in sequence, is employed.

The tip inserts are little cones (Figure 13) with the precise angle of the ULD ogive as it approaches the centerline of the bullet. This angle is the same for all ULD ogive bullets regardless of caliber. Therefore, the same tip inserts can be used on a wide range of calibers, limited only by the diameter and length of the tip compared to the rest of the bullet. At this writing, two different tips are available, the TIP-50 and the TIP-30.

The TIP-30 is made to fit into calibers around the .308 size, usually from about .284 (7 mm) up to around .323 (8 mm). The limiting factor is appearance and balance on the smaller caliber side: the tip can be too much of the total ogive if the diameter of the bullet is too small. The limit on the upward side is the thickness of the bullet jacket at the open end, which typically is much heavier in larger calibers. The difference between the diameter of the stem on the insert and the base of the cone to which it is attached is twice the wall thickness of the jacket, or more.

From about .338 up to .510 caliber (50 BMG), the TIP-50 is more satisfactory than the TIP-30.

Since this concept was introduced, the ULD-TIP bullets have been used around the world in innumerable matches and long-range shooting situations (some having to do with paper targets, others involving targets with an additional two dimensions). The feedback has been overwhelmingly positive.

The ULD design, with or without a tip, is not a universal cure for every load, caliber, and twist rate. It is simply the highest practical BC design regarding the bullet shape, incorporating about 15 percent higher potential accuracy due to the reduction in muzzle gas redirection caused by conventional boat tails (both flat base and RBT base bullets tend to blow the muzzle gas away in an expanding ring, whereas the boat tail tends to focus the base or at least some of it into a ball in front of the emerging bullet, causing some buffeting with the turbulence created right in front of the bullet). The conventional boat tail has slightly higher BC, but the RBT makes up for that with a bit more potential accuracy or at least partial elimination of a source of bullet dispersion brought about by the boat tail.

BC has been discussed at length, and it should be clear that so long as accuracy is acceptable, higher BC is better. But at some point the factors that create ever higher BC reach a level that will adversely affect accuracy. Once most efficient possible shape is achieved, such as the ULD- TIP design, then in a given diameter of bullet all that can be done to further increase the BC is to make the bullet heavier. This can be done by using higher density material (tungsten, gold, silver, osmium, uranium, and so forth) instead of lead, or it can be done by using more lead.

Obviously, if using enough lead, the bullet gets too long to be stable in any practical twist rate.

Rebated Boat tails

A flat-based bullet is formed by seating the lead core into a jacket using a CS-1- core seat die. The jacket base is flat. It pushes against a flat punch and stays flat. A rebated boat tail refers to a bullet having the base of the jacket formed in a truncated conical shape, with a small step or shoulder between the shank of the bullet and the start of the boat tail angle. A conventional boat tail bullet has no step. The boat tail angle, usually from 8° to 12° relative to the centerline, just starts at the end of the shank and tapers back to a smaller flat base about 60 percent of the bullet diameter.

There are two purposes for a boat tail. The most important is to reduce the amount of drag that occurs when air rushes back to fill the void left by the moving bullet. Turbulence occurs when the sharp right angle of a flat base bullet passes a given point in the air, and the molecules of air rush in a chaotic way to equalize the pressure back to normal atmospheric levels. In a simplified way of looking at base drag, you could say that moving the bullet through the air creates a vacuum behind the bullet that "pulls back" on the bullet.

An angle on the bullet shank near the base, shaped like a boat prow, helps the air to smoothly flow back together. In effect, this reduces the amount of vacuum or turbulence and thus cuts down on the "pull" at the base of the bullet. As a result, there is less loss of speed over the same range and more energy on target, plus a flatter trajectory.

A second purpose for the boat tail base is to help get the bullet into the case neck without catching the case edge and bending it. A slight bevel would do as well, but these would not have as much effect on reducing drag.

THEORY BEHIND BASE DRAG REDUCTION

A conventional boat tail base is most useful when a bullet is fired over very long ranges, or when a bullet is fired at speeds below that of sound. As soon as a bullet breaks the first sound

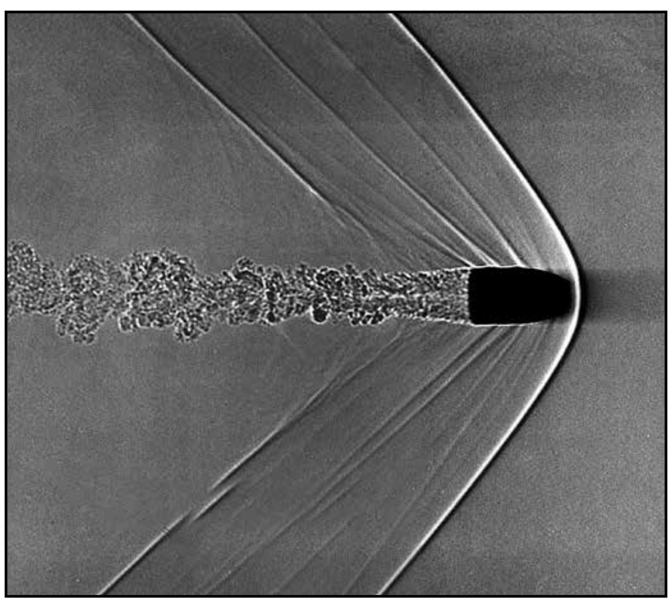

***Figure 14**: A shadowgraph image of a supersonic bullet. The bow shockwave is clearly visible as the V-shaped line at the front-most tip of the bullet (far right).*

barrier (about 1,130 fps at sea level under standard conditions), it compresses air molecules so rapidly that they don't have time to get out of the way, and they form a dense V-shaped pattern of highly compressed air that seems to travel along with the bullet (Figure 14).

When the bullet goes supersonic, it feeds energy to the air so fast that the base drag is a small portion of the total loss. The base drag is just as big a loss as ever, but now the bullet has something much bigger to worry about. Since much cannot be done about the shock wave except to make the bullet as streamlined as possible (which shapes the shock wave to be more streamlined, as well), work on the base drag.

At high velocity, the base drag component might cause up to 15 percent of the total loss of velocity, but when the bullet slows down to below the speed of sound, the base drag may cause up to 40 percent of total velocity loss. Pistol bullets, which travel much closer to subsonic speeds, and rifle bullets for muzzle loaders, benefit far more in total drag reduction from a boat tail design than would a high velocity rifle bullet.

On the other hand, a high speed rifle bullet generally is used at longer ranges. This means that even though the boat tail benefit is much smaller than for slower bullets, it has a long time to act, or at least a longer range over which crosswinds can work on it. A 40 percent improvement in ballistic coefficient at 100 yd. would only be a few inches of vertical distance on the target. A 15 percent improvement in ballistic coefficient in a 1,000 yard bullet might mean hitting the target or missing it.

DISADVANTAGES OF THE BOAT TAIL BASE

The boat tail adds some length to the bullet, and makes a cup or hollow base ineffective for sealing the bore. Very light, short bullets might not be able to use a boat tail base without losing their small bearing surface. Boat tails also contribute to inaccuracy in two ways. First, they tend to direct muzzle blast gasses into sharp focus like the central post of a water nozzle directs water into a stream. The result is that instead of the expanding ring of gas that you get from a flat base, a ball of turbulent gas is blown around the bullet and breaks up just as the bullet flies through it, adding from 10 percent to 15 percent more dispersion than a comparable flat base bullet would experience.

Second, the boat tail angle tends to focus hot gas in the bore toward the junction of the rifling and the bullet, as gas pressure, acting at right angles to all surfaces containing it, is vectored at 90° to the BT angle and attempts to peel the boat tail and barrel junction apart. If successful, the gas compresses the boat tail portion of the bullet slightly, pulls the bullet jacket slightly away from the bore, and lets more gas rush past the bullet along the rifling bottom, cutting the bullet and eroding rifling.

ADVANTAGES OF THE REBATED BOAT TAIL BASE

If the angle of the boat tail is interrupted by a small but fairly sharp right angle, just as the boat tail joins the rest of the bullet shank, both

Figure 15: RBT die set.

the gas cutting and the muzzle blast focusing effect are greatly reduced, even eliminated. The shoulder acts as a “spoiler” to the laminar flow of muzzle gas, which tends to follow the bullet outline because of the smooth boat tail shape, just as the air follows it in the other direction.

A minor advantage to the RBT design over the BT is that the exit from the muzzle effectively takes place much faster. How so? Because a boat tail exiting the muzzle is like a tapered cork being pulled out of a bottle of sparkling wine: it releases gas slowly as the gap widens little by little, and any slight difference on one side of the gap changes the pressure acting on the bullet and shifts the bullet path slightly.

The RBT is more like a flat base bullet in that the moment the rebate edge passes the muzzle, the restriction drops away instantly to a smaller “cork” and gives the gas a much larger orifice for escape. This gives less time and lower pressure for a slight angle or dent in the muzzle area to direct gas unevenly around the bullet, and helps to insure consistent straight exits from the barrel.

AVAILABLE RBT DIE SETS

Rebated boat tail die sets (Figure 15) are made in the type -S, and -H dies, but not in type -R because of the fragile point-forming punch edges and relatively poor alignment of the slotted reloading press ram and head. If wanting to make RBT bullets, swaging has become a serious project and a real swaging machine will be needed.

REBATED BOAT TAIL PISTOL BULLETS

A short pistol bullet such as the .45 ACP can sometimes be made as a rebated boat tail by seating the core in a truncated conical (TC) shape point-forming die, the same as it is making a FMJ bullet, but then using a Keith nose punch to push the bullet backward into the same die, open end first. The solid end of the jacket, having already been formed into a fairly good boat tail shape, fits down into the Keith punch well enough so that it can expand sideways and take on the shoulder. The open end takes on the shape of the point-forming die.

This simplified, low cost way to make a RBT bullet does NOT work if the ratio of bullet length to diameter is much over 1.7:1. That is, a .452 in. bullet that is less than .7684 in. long probably will form a reasonable boat tail without too much taper in the shank portion. But an inch-long .458 probably will not.

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Shotgun Slugs and Airgun Pellets

Shotgun slugs are just bigger calibers to the bullet swager. Everything said about other bullets applies to them. Jacketed slugs using ¾ in. O.D. copper tubing or pipe caps for jackets can be made, or draw jackets from strip copper can also be made. Another option are lead slugs of conventional or exotic designs (Figure 16). But regardless of what is made, if the slug is 16 gauge or larger, it will require -H type dies and one of the larger Corbin presses. The more simple shapes, in soft lead, can be swaged in the Mega-Mite hand press, even as large as 12 gauge. Small shotgun slugs, such as the .410 gauge, are below .458 diameter and can therefore be swaged in the S- Press.

The 20-gauge, 16-gauge, 12-gauge, 10-gauge, 8-bore, 6-bore and even the huge 4-bore can all be made rather easily using any of the hydraulic presses that accept type -H dies. Corbin can even build special dies that make helical fins on the slugs, to spin them from the muzzle blast gas flow and keep them spinning all the way to the target. These use punches with built-in ejectors, not a standard set of tooling by any means, but entirely practical. A number of successful businesses have been founded on the use of these tools. Their products can be found in mail order catalogs and on the internet as well as in some better-equipped gun stores.

In most cases, you would want to swage the core in a CSW-1-H core swage die, then put it into a CS-1-H core seater and form the special features such as a post in a hollow base (keeps the wad from being blown inside the cavity) or a saber-toothed hollow point. Finally, you might put this into a PF-1-H point form die to shape the ogive.

There is a great deal of similarity in design between certain shotgun slugs and airgun pellets. In regular -S dies, the airgun pellets can duplicate the slugs. But the airfoil-stabilized design is just too delicate to work in a scaled-down version. The parts become far too fragile compared to the required swaging pressure (works fine on paper, however). Dual-diameter pellets offer excellent performance in a design similar to a Foster-type shotgun slug, but with a short Keith SWC nose.

A dumbbell or "diablo" style shotgun slug can be swaged by using a split sleeve around a lead core, the assembly of which goes into a CS-1-H die. The larger head and base are swaged to the diameter of the die, and the split sleeve maintains a smaller waist in the middle. After forming and ejecting the slug and sleeve, a thin-edged tool is used to pry apart the two halves of the sleeve, revealing the slug with the hourglass shape. This does not work for small calibers because

Figure 16: *Examples of some exotic slug designs.*

Figure 17: *Airgun pellets.*

the sleeve becomes too fragile for the pressures, but it works well enough for shotgun slugs.

Airgun pellets (Figure 17) differ from other lead bullets in respect to the propelling pressure and velocity, which are generally much lower than with either modern cartridge guns or black powder muzzle loaders. Pre-charged, high power airguns are moving toward these levels, however. Today, Corbin makes dies for airgun projectiles that fit .25, 9 mm, .45, and .50 caliber airguns. Most of these larger bore airguns carry compressed air in a reservoir that is filled from SCUBA tanks, with pressures of 2,000 to 5,000 psi and higher.

The main concern of the airgun pellet designer is obturation with minimal friction. Working with relatively low pressure, the airgun pellet must put as much of it to work as possible. Sealing the bore immediately against any pressure leaks around the pellet (obturation) is critical, but so is minimizing the amount of friction produced by forcing the pellet through the bore. Because the pressure is relatively low, the pellet typically needs to be light weight for the diameter. These design parameters point toward a deep hollow base with thin edges.

Two designs have proven themselves in international match competition, and the choice between them is a subject for debate. One is the straight-sided hollow base with a thin base edge, having a fairly sharp internal angle near the base that joins a more gentle angle as the walls become thicker toward the nose. The shape of the hollow cavity can be a radius at the end, flat, or even a sharp point (for heavier pellets).

The sharper inside angle near the open base helps direct the air pressure to push the thin "skirt" of the pellet into the rifling quickly so that very little air pressure escapes before the base is sealed. Making the angle too sharp reduces the effective area and thus decreases the total force pushing the skirt outward, whereas making the angle too shallow or blending it into the same angle as the rest of the hollow base cavity vectors the air pressure force closer to the axis of the bore, so that a point is reached where the total force acting to expand the skirt at the open edge is again reduced, and air pressure escapes around the base.

Fortunately, airgun pellet swages are inexpensive experimental tools compared to exotic shotgun slug shapes. A simple LSWC-1 die and low-cost base or nose punch can be tried without undue cost, and the best design for each gun in one's arsenal can be determined experimentally. The simple, single diameter pellet that is essentially a lead semi-wadcutter hollow base projectile may work best with the flat tip, round nose shape, or even with the truncated conical (or Keith) nose.

Dual diameter pellets are made either in two dies (the standard LSWC-1, as described above for the single-diameter pellet, is the first operation, followed by a DDS-1 dual-diameter sizing die), or in one special pellet-forming die that combines the weight adjusting features of the LSWC-1 with the dual diameter features of the DDS-1. This is called the DDS-1- SC or DDS-1-HC, depending on which press it is made to fit. The custom die has both weight adjustment, and adjustable ratio of the length of the two diameters. A special adjustable-length internal punch controls the position of the nose

within the die, which in turn controls how long the minor diameter section will be compared to the major diameter or skirt section.

The best advice would be to try the lower cost solution first. Experiment with weight, nose and base shapes, and then with diameters. When the best combination of these factors is found, see if the results are good enough or if a possible improvement in bullet design would actually have a noticeable effect on the score. If already shooting 499 out of 500 possible, and fairly sure that sometimes a shot is thrown by improper technique, then it may be a waste of money to try to make a better pellet. If getting lower scores and fairly sure that ability and technique would deliver better ones if it were not for the unexplained flyers now and again, perhaps a different bullet design will prove to be useful.

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Bullet Makers' Tools

Some of the dies and equipment that bullet makers use are not necessarily part of a basic swaging set but are used to make special features in the bullets and may be used with several kinds of basic swaging sets. Features such as the dual-diameter, serrated jackets, or cannelures can be added to nearly any style of bullet. New ideas are constantly being developed, so there may well be other tools now which are not described in this book. But following are ones currently being made.

DUAL DIAMETER SIZER DIE (DDS-1)

This die is made for all of the Corbin presses, in type -M, -S, and -H. The purpose is to form a bullet that has two diameters. The nose or ogive section of the bullet rides on top of the rifling to align and guide the bullet with very little friction, while the rear portion of the bullet is left full diameter to engage the rifling.

The DDS-1 die is a final step. It is used with other dies, not by itself, except in special custom versions for pellets and lead bullets. First, make the bullet at its major diameter. Then push it into the DDS-1 die to whatever length you wish to have reduced. Nearly the entire bullet can be reduced, or just a little of it.

JACKET TRIMMING DIE (ET-2)

The ET-2 die makes it possible to precisely trim a long bullet jacket to shorter lengths. High quality bullet jackets are expensive to produce and stock, making it more likely that a company could stay in business by making the longest practical jackets for each caliber and stocking them than by investing in every possible length in each caliber. The longest jacket can be easily trimmed to make any shorter length using the ET-2, making it unnecessary to tie up money in more than one length per caliber. It is possible to get enough of one length to break into the discount volume, and the jacket company may be able to stay in the jacket business (most of them have dropped out of it for economic reasons).

Figure 18: Examples of bullets showing cannerlures.

CANNELURE, KNURLING, AND BULLET GROOVING TOOLS

Cannelures (Figure 18) are serrated grooves rolled into a jacketed or lead bullet, either to help identify the bullet, to strengthen the jacket, to use for crimping the case mouth, or just to tighten the bullet's grip on the case. The word is pronounced “CAN-a-loor.” There are two kinds of Corbin cannelure tools.

The Corbin Hand Cannelure Tool, HCT-1, (Figure 19) handles calibers from .172 to .458. A new version introduced in July 2002 has an extra set of holes for the pivot shaft, which are raised to allow the caliber range to extend beyond .458, all the way to a .72 caliber, so long as the bullet length doesn't interfere with the crank handle. The tool can be assembled with

Figure 19: Corbin's HTC-1 Hand Cannelure Tool.

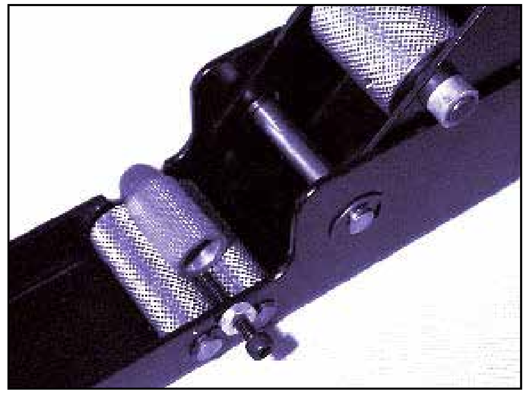

Figure 20: HCT-2 Lead Knurling Tool.

the upper section hinged by either set of holes for two ranges of overlapping calibers.

It can put adjustable depth and adjustable position cannelures on copper or gilding metal jackets as well as hard or soft lead bullets. The HTC-1 Hand Cannelure Tool uses a roller V-way to support the bullet, and a padded handle that pivots a U-shaped channel down over the bullet, and presses a hardened roller wheel against the bullet shank. Turning a crank shaft rolls the cannelure into the bullet in one or two turns. Four or five bullets per minute can usually be done with one.

A special version of the hand cannelure tool is used to make a waffle-pattern or knurled surface on lead bullets, which holds far more lubricant than a ring. This tool is called the HCT-2 Lead Knurling Tool (Figure 20). The main difference between it and the HCT-1 is that the HCT-2 has three diamond pattern knurling wheels instead of a pair of smooth V-way rollers and a single cannelure wheel. A number of firms have used this pattern, including Hornady and Buffalo Bullets, in their lead swaged bullets.

Another version of the hand tool is the HCT-3 Bullet Grooving Tool. This tool rolls two grooves at a time onto the bullet. The grooves are wider than those on the cannelure tool, which is really made for jacketed bullets or straight pistol cases. Corbin prefers to swage a lead bullet in a die that is a little smaller than the final caliber, or even just in a core swage die, knurl or groove it, apply bullet lube, and then swage it to final size in a core seating or point-forming type of die. This maintains perfect lube grooves with no air pockets in the lube, compressing them slightly and bringing the lube right to the surface of the bullet so it looks like it was machined instead of squished in.

HEAT TREATMENT OVEN

Melting lead cores for bonding to the jacket and heat treating either jackets or lead itself can be done in the HTO-2 Heat Treatment Oven, which features a digital control with thermocouple sensing and feedback. The oven normally runs on 120 volts AC, but can also be ordered in a 240 volt model. Capable of up to 2,100° F, the HTO-2 offers gunsmiths and tool makers a

Figure 21: SDD-1 is a "crown-of-thorns" draw die.

convenient, fast-heating furnace that can melt gold, aluminum and lead alloys or heat-treat tool steels. The furnace has a cavity size of about 4.5 in. x 5 in. x 6 in. deep. It has a low thermal density ceramic liner that allows rapid heating and fast cycling time, and is highly desirable for fast cycle time so you can process a lot of jackets in a hurry at low operating cost.

FLAMELESS HEAT GUN

A handy way to generate up to 1,000° temperatures at low cost without flames is the Flameless Heat Gun, FHG-1. Like an overpowered hair dryer, the FHG-1 uses a fan and electric heating elements to blow a stream of superheated air for annealing, bonding, and heat treatment. It is slower than a propane torch, but also heats more evenly without risk of going over temperature and burning the parts. The heat gun runs on 120 volts AC.

SDD-1 SERRATOR DRAW DIE (FULL LENGTH)

The SDD-1 (Figure 21) is a "crown-of-thorns" draw die, with small, sharp adjustable points projecting inward. A bullet jacket is typically placed over a drawing punch and pushed through the die. The points cut a fine, shallow groove in the outside of the jacket, so that it will tend to separate and peel back in evenly divided petals along these stress-relief lines.

Typical applications include making fragmenting bullets, which have limited penetration. These might be used in security and police work, as for example in a prison where a ricochet is almost certain among all the concrete and steel with conventional bullets, or in varmint hunting, where the bullet needs to disintegrate when it hits the ground to avoid skipping off over the horizon and punching a "cancel" hole in the shooter's welcome ticket to that particular farm.

SDD-2 SERRATOR DRAW DIE (ADJUSTABLE, PARTIAL LENGTH)

Sometimes, a person wishes to make a bullet that opens quickly and reliably with good, even expansion, but then stops expanding about midway or just past the ogive. A jacket thick enough to resist expanding may also resist opening, especially at lower velocities (which may be the result of long range impact or perhaps just a low muzzle velocity). Subsonic rounds with boat tail bases and blunt round noses may fall into this category. So do many conventional hunting bullets.

The answer is to serrate only the forward portion of the jacket. This can be done two ways. A special broaching punch can be made to cut into the jacket from the inside as you push it down from the open mouth toward the base. This works if the jacket is thick and tough enough to withstand the force without Collapsing in front of the broach teeth. Most copper tubing jackets can be serrated this way.

The distance that the jacket is pushed into the die determines how much of the ogive will be serrated. This is precisely set by the floating punch holder position. A flat-ended punch within the die (internal punch) pushes the bullet back out again and irons the ridges flat. This die, like the SDD-1, is made for a specific diameter of jacket rather than a caliber of bullet,

except that in cases where it is made to fit the jacket after a core is seated, it is very close to accepting the final caliber size. The SDD-1, on the other hand, accepts the jacket prior to seating a core, which means the die bore is usually several thousandths of an inch smaller than the final caliber.

The six hardened steel points are individually adjusted for depth when the die is built and tested. They are replaceable and adjustable, but unless there is good reason, it should not be done. Without an alignment probe, which fits the bore and has a reduced section held concentric with the bore against which the points can be gently run to set them, it is difficult to get the points set the same depth. Some people try to set the depth to cut farther into the jacket, but this is not wise because the metal displaced by the cut has to go somewhere, and the force and wear on the points becomes much greater as you go deeper. There is no practical advantage to cutting more than a shallow groove in the jacket, since even a shallow cut will channel the impact force and concentrate it along the stress lines.

DCD-1 DISK CUTTER DIE

The disk cutter die is used to make round disks out of flat strip. It can be made to cut copper strip, cardboard, or felt to make wads. The copper disks are sometimes used as a seal, pushed to the bottom of a tubing jacket to close off the little hole that may be left, for purposes of bonding the core. Cardboard and felt may be cut into disks to make grease wads, over-powder protection wads for lubricated bullets, or shotshell wads.

The typical disk cutter die is built for a given material thickness and width. Some materials can be cut even with the power of a reloading press, while others may require a Hydro-Press. The dies are similar in design, however. They screw into the press from the bottom side of the head, which is different from nearly all other kinds of dies. In other words, you would hold the die below the press head and put it up into the threaded hole rather than screwing it down into the hole from the top (the normal way).

BGK-1 BASE-GUARD MAKER

The Base-Guard maker is similar to the disk cutter die, except that it uses 0.030 in. thick copper strip, and the cutter punch has a small pin projecting from the face, which penetrates the strip just before the disk is cut free.

The use of Base-Guard disks has been covered in previous chapters. It scrapes fouling from the bore with each shot and helps keep the bore clean, while sealing the chamber gas behind the bullet to prevent gas cutting and leading. It is a sort of "super" version of a gas check, only it is easier to make and uses slightly less copper, and helps clean the bore instead of just protecting the bullet. BGK-1 dies can be built in type -R, -S, and -H for all types of suitable presses.

BSK-1 BALL SWAGE KIT

The ball swage kit can be made in type -S or -H. It consists of two dies, a CSW-1 core swage die with rounded concave punch ends and a special hemispherical guided swage die. Each size of ball swage comes with instructions that tell you the proper weight of lead to make a given perfect round ball out of pure lead. This weight can be adjusted slightly to compensate for slight differences in lead density.

Once the proper weight of cores has been formed, they are lightly lubricated and placed in the lower half of the hemispherical die. The die is an assembly with two sliding halves, guided by a pair of rods. The top part of the die screws into the floating punch holder (without the usual retainer bushing) and the lower part screws into the press ram. Specific instructions come with each die and supersede any earlier printed

Figure 22: *BSK-1 ball swage kit.*

material, since it is possible that improvements and changes may be made from time to time.

Balls from .25 caliber to 1 in. diameter have been made in various BSK-1 die sets, with a degree of perfection seldom found in casting. The speed of operation, even using three strokes of the press, far exceeds the total time required to make an equal number of balls by melting lead, if considering the total project time and not just the pouring of hot lead into the mould. With the BSK-1, lead does not need to be melted, nor is there any waiting for equipment to cool down to clean it up and put it away.

FX-1 BULLET FIXER KIT

The FX-1 can be made in type -S or type -H. It is for the enterprising person who has purchased a truck load of pulled military bullets of the conventional lead-filled variety (not pyrotechnic or explosive rounds, nor armor-piercing ones that have a core too hard to be moved around), and wishes to make them more accurate, to remove or minimize the pull marks, and to improve the appearance for resale. It is also for the person who has a quantity of bullets that have been in some way damaged, such as culls or pulled bullets from a commercial loading operation, who wishes to fix them.

OTHER TOOLS AND DIES

Lead wire extruders, core cutters, and core moulds were discussed back in the chapter on making lead cores. Jacket and bullet draws dies were covered, and so were the copper tubing and strip jacket drawing dies. Gas checks and Base-Guards were discussed.

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